

N 84 - 33364

# **Aeronautics and Space Report of the President**

***1983 Activities***



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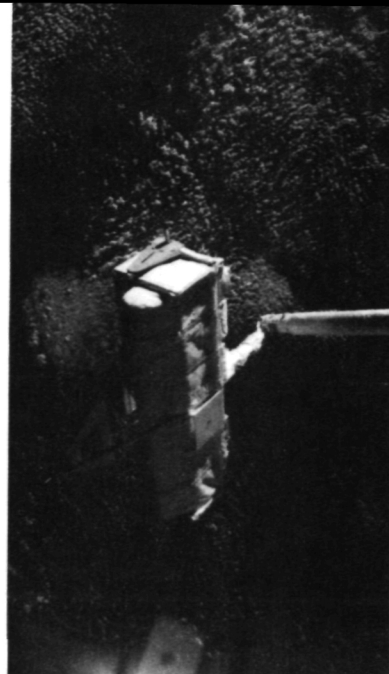
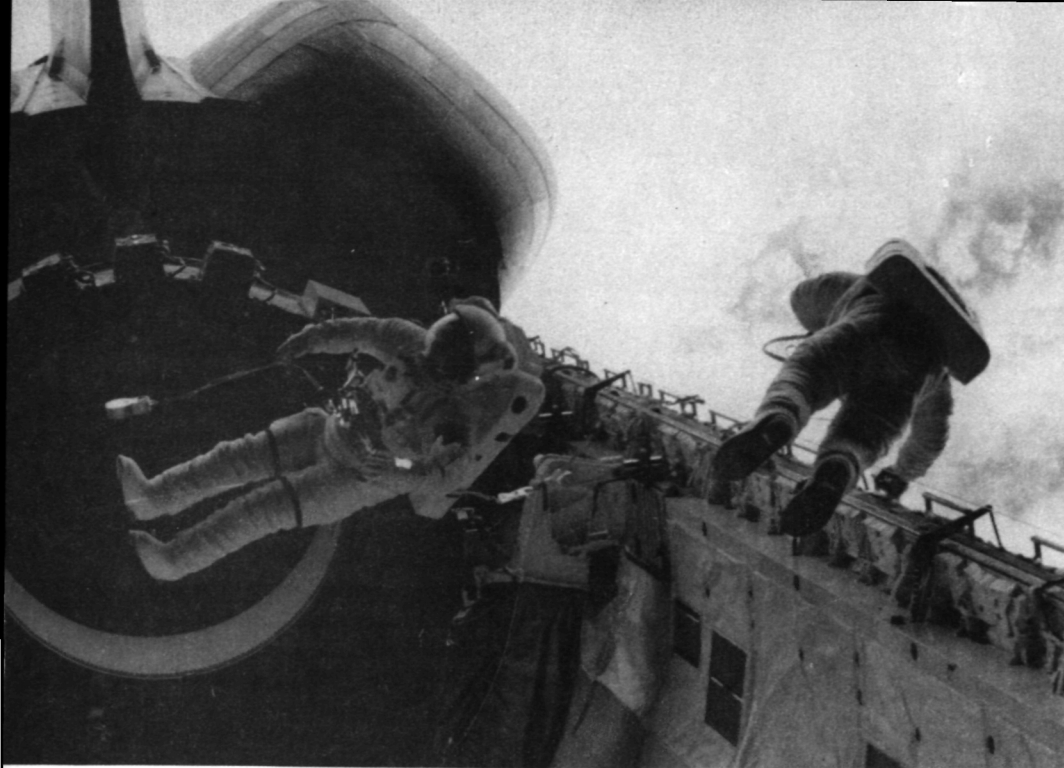


**National Aeronautics and Space Administration  
Washington, D.C. 20546**

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## Appendixes



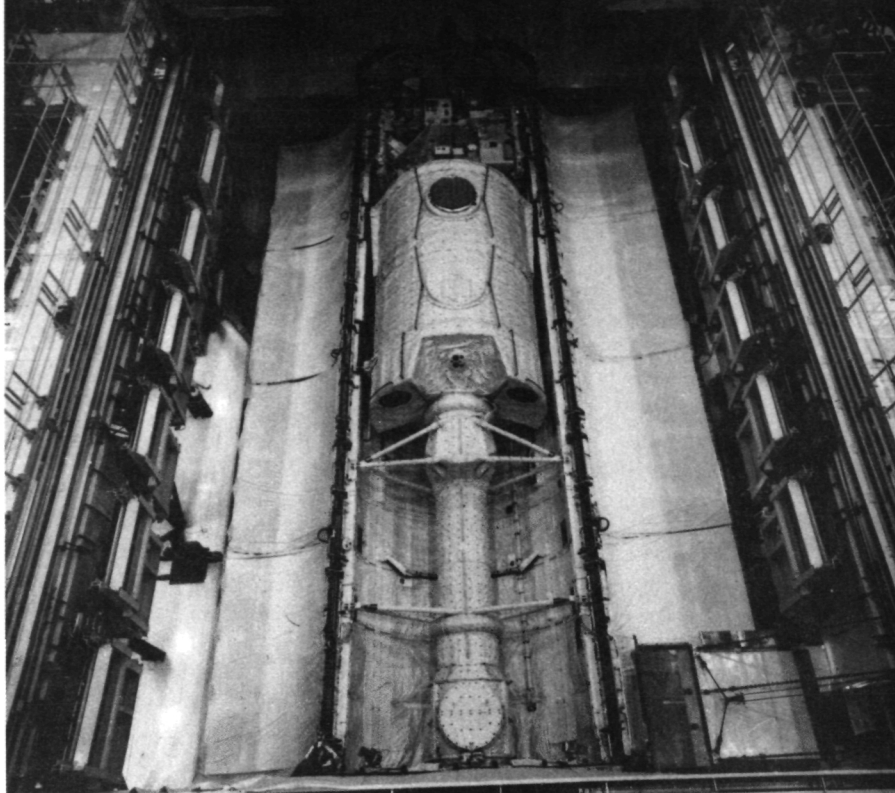
## Aerospace Events of 1983

Four operational flights of the Space Shuttle make a busy schedule. On STS 6, above left, astronauts Story Musgrave and Donald Peterson practice using tools in *Challenger's* cargo bay in April—the first U.S. spacewalk in nine years. Procedures are to be used in repairing an ailing satellite on a later mission. Above right, *Challenger's* remote manipulator arm grasps the free-orbiting Shuttle Pallet Satellite, *SPAS 01*, during exercises in June on STS 7, which deployed and later retrieved the satellite. Astronaut Sally Ride at left, mission specialist on STS 7, uses a screwdriver to clean an air filtering system in the Shuttle mid-deck. "TFNG" on her constant-wear garment stands for "thirty-five new guys," the 1978 class of astronauts. On STS 8 in August, astronaut Guion Bluford, below left, mission specialist, checks the sample pump on the continuous-flow electrophoresis experiment, designed to separate biological materials.

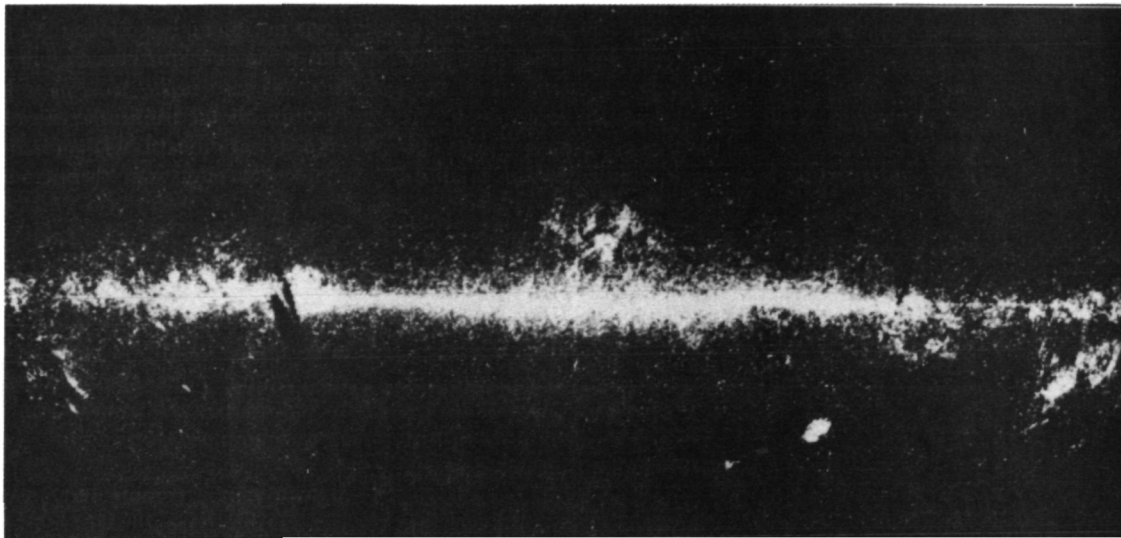


Photo by NASA

Spacelab 1, at right, is installed in the orbiter *Columbia* for launch on STS 9 in November. The crew access tunnel, the only major piece of Spacelab hardware made in the United States, connects the European-built pressurized laboratory to the orbiter's crew compartment. Beyond the laboratory module, the pallet exposes experiments directly to the space environment. STS 9 carried the largest crew launched into space to date. Clustered in the aft end of Spacelab (below, clockwise from bottom center) are John Young; Ulf Merbold, European Space Agency payload specialist from West Germany; Owen Garriott; Brewster Shaw; Byron Lichtenberg; and Robert Parker.



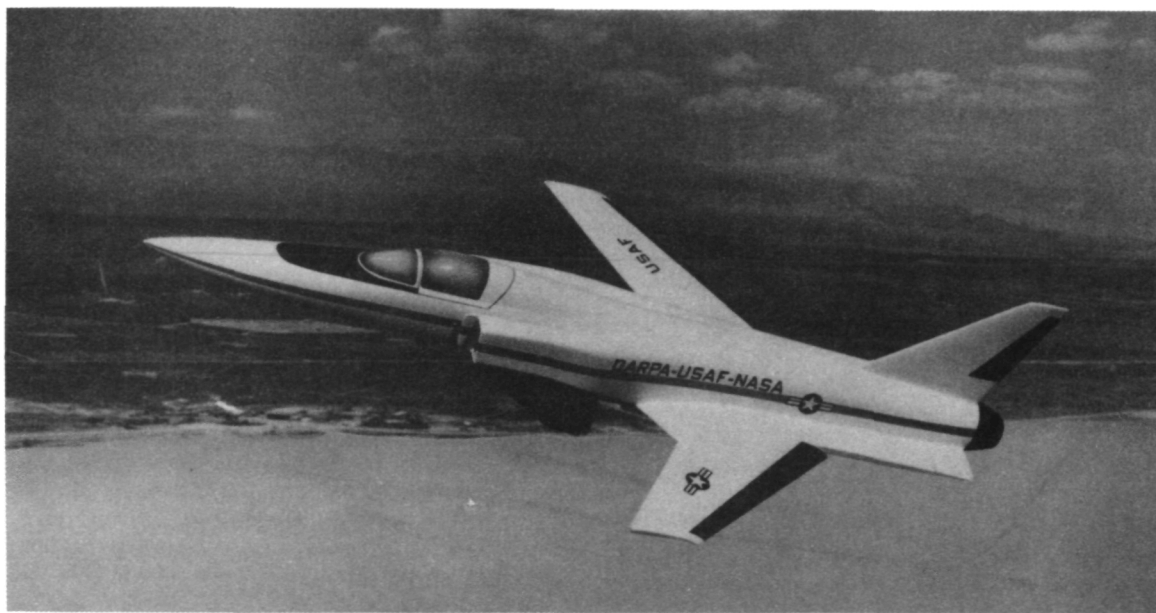
A projection of the entire sky assembled from data from the Infrared Astronomical Satellite (*IRAS*, launched in January) shows more than 250,000 infrared point sources. The plane of our galaxy runs horizontally across the middle. The bright region above the center is in the Ophiucus constellation, and the similar region at right just below center is in Orion. Both are intense regions of star formation. Two white blobs below center toward the right are the Large and Small Magellenic Clouds, small galaxies orbiting the Milky Way.





A Global Mapped Vegetation Index image, compiled from June 19-26 data from *NOAA 7* and *8* satellites, depicts the extent and "greenness" of vegetation in the United States and parts of Canada and Mexico. The weekly composite is produced from global data collected daily. The darker the shading, the more vegetation present.

Aeronautical research continued during the year. The X-29 forward-swept-wing aircraft (below) began extensive ground testing in the Defense Advanced Research Projects Agency-Air Force-NASA program to develop integrated, advanced aerodynamic, structure, and flight control technology. At bottom, in the USAF-NASA advanced fighter technology program, the AFTI F-16 aircraft incorporates digital fly-by-wire control and canard surfaces. Flight tests of the digital flight control system were completed in 1983.





# Summary

The 25th anniversary year of the official United States aeronautics and space program was marked by four operational Space Shuttle missions and twenty-seven other U.S. payloads launched into orbit. Space Shuttle missions—three of them flown by the fleet's second orbiter, *Challenger*—deployed satellites in space for commercial and government users, retrieved a satellite from space for the first time, and carried commercial, university, and government experiments in many disciplines in addition to the 10-day maiden flight of the European-built Spacelab with its more than 70 experiments in life sciences, astronomy, solar physics, space plasma physics, earth observations, and materials processing.

The Shuttle carried into space the first U.S. woman astronaut, the first black astronaut, and the first European specialist aboard a U.S. spacecraft. On one mission, two astronauts left the orbiter's cabin for extravehicular activity to work in the open cargo bay. The Shuttle's Spacelab mission in November carried a crew of six, the largest launched into space to date.

Of the 31 U.S. payloads launched into orbit during 1983, 11 were by the Department of Defense and 20 by NASA (1 for DoD). These launches included 4 Shuttle orbiter flights and 5 satellites launched from the Shuttle; 22 satellites were put into orbit on 18 expendable launch vehicles, with 1 DoD vehicle launching 3 satellites at once and 2 launching 2 each. Satellites included 10 launched by NASA for communications (all but 1 for paying customers), 3 to monitor the weather (2 by NASA for the National Ocean and Atmospheric Administration and 1 by DoD), 1 navigation satellite by DoD, and 4 scientific satellites (3 by NASA in international projects and 1 for DoD). DoD launched 9 other military satellites. Both NASA and DoD began actions responding to the Administration's endorsement of increased commercial development in space activities.

The Infrared Astronomical Satellite (*IRAS*) launched in January in a U.S.-Netherlands-United Kingdom project surveyed the entire sky to make hundreds of new discoveries in the universe, including five comets, many asteroids, formation of new stars, and the possible beginning of solar systems around Vega and other stars. Three other scientific satellites also began studies in space during the year, as four planetary spacecraft launched in the 1970s continued to return data on the interplanetary medium.

*Pioneer 10* left the solar system in June 1983, the first man-made object to do so. The International Sun-Earth Explorer *ISEE 3*—which completed its studies of the sun begun in 1978—was maneuvered onto a path to encounter the Comet Giacobini-Zinner in 1985. New satellites were launched to upgrade communications, navigation, and weather networks.

Cooperative international space activities increased with operational use of the Shuttle in addition to cooperative satellites; scientists from 14 nations supported experiments on Spacelab 1. In the United Nations, however, differences arose over the role of the Committee on the Peaceful Uses of Outer Space in questions of use of the geosynchronous orbit and of military use of space, which the United States believes are appropriate to other U.N. committees or the International Telecommunications Union.

In March, a presidential directive called for a long-term research and development program to explore strategic defense technology to eliminate threats from ballistic missiles. DoD prepared a program that will seek to develop a nonnuclear system that could destroy enemy ballistic missiles and warheads throughout their launch-to-impact sequence, to protect military and civilian resources in the United States and allied countries.

During the year, both DoD and NASA made advances in aeronautical technology for improved aircraft, and the Federal Aviation Administration, NASA, and DoD continued research to improve the safety of the nation's airways.

This summary chapter surveys calendar 1983 achievements in the U.S. space and aeronautics program by function. The succeeding chapters present the work of individual agencies in more detail.

## Communications

Both international and domestic communications networks increased and improved their services in 1983 to meet the still expanding demand. Of the 10 communications satellites launched by NASA during the year, 5 were for commercial U.S. domestic use, 4 were international, and 1 was leased by NASA for satellite communications. An increasing number, 4 of the 10, were launched from the Space Shuttle, and 6 were put into orbit by expendable launch vehicles. European competition for launch services increased—

with a European Ariane launching one of the two 1983 Intelsat satellites. U.S. commercial expendable vehicles may compete in the near future. U.S. industry remained the dominant supplier of communications satellites to the world community. Both government and industry continued developing new technology, with NASA pursuing high-risk advanced technology for potential use of the multiple-frequency bands.

#### *Operational Space Systems*

**INTELSAT and INMARSAT.** The International Telecommunications Satellite Organization's revenues and circuit use continued to grow at a rate of more than 20 percent, and the sixth and seventh Intelsat V series satellites were launched in May and December. One more Intelsat V and two V-A satellites were scheduled for 1984 launch. INTELSAT placed orders for five Intelsat VI satellites with about 25 percent greater capability than the V series. Six new ground stations joined the global system.

The International Maritime Satellite Organization's activities also continued to grow in its second year of operation, providing communications for ships at sea. INMARSAT requested proposals from industry for additional maritime capability, as it began leasing services through Intelsat satellites already in orbit.

**Domestic Communications Satellites.** The Federal Communications Commission reduced the orbital spacing requirement between domestic satellites to permit further growth and the introduction of new systems. In addition to the 5 domestic communications satellites launched in 1983, the FCC has authorized the launch of 19 new satellites, to bring the total to 38 by 1987. The commission also granted permits to eight companies to construct Direct Broadcast Satellites for direct-to-home television service, received three other applications, and invited new proposals. It intends to use the international satellite plan agreed on at the 1983 Region 2 Regional Administrative Radio Conference held in Geneva as the primary basis for domestic direct broadcast.

**Military Communications Satellites.** Military Satellite Communications (MILSATCOM) and leased commercial SATCOM circuits continued to support the command and support forces and the strategic and tactical, nuclear and conventional forces worldwide in 1983. In the Defense Satellite Communications System serving the command and support forces, the first DSCS III satellite, launched late in 1982 with improved physical and electronic survivability over the existing DSCS II series, became fully operational in May 1983 for superhigh-frequency, high-data-rate communications of the Department of Defense, Department of State, and allied nations. Other DSCS IIIs are in production and ground and ship terminals continued to be upgraded.

The Air Force Satellite Communications System (AFSATCOM), serving tactical nuclear-capable

forces, achieved full operational capability in December. Four Leased Satellites (LEASATs)—the first planned for launch from the Shuttle in 1984—and three FLTSATCOM satellites—the first in late 1985—will extend the Navy Fleet Satellite Communications System's more than 17 spacecraft years of almost worldwide low- or moderate-rate service to strategic and tactical conventional forces.

A contract was awarded for full-scale development of the MILSTAR communications satellite and for a control capability able to survive conflict, as the three military services continued development of terminals with maximum commonality and interoperability. Terminals will be tested on *FLTSATCOM 7* and *8*. Technology development also continued for laser communications from space to submarines, with tests expected in 1984–1985.

**Military Navigation Satellites.** Two improved TRANSIT navigation satellites, *NOVA 2* and *3*, were delivered in October 1983 for upgrading the Navy's five-satellite constellation serving numerous military and civilian users for the past eight years. The joint-service Navstar Global Positioning System began production with the award of a contract for 28 GPS satellites. GPS deliveries beginning in 1986 are to lead to full operational capability by the end of 1988, to provide precise radio-positioning and navigation information supporting DoD missions worldwide.

#### *Space Communications Experiments*

**Experimental Satellites.** The international COSPAS-SARSAT satellite-aided search-and-rescue program demonstrated that satellites could save lives by finding aircraft and vessels in distress. The first U.S. satellite carrying SARSAT equipment, *NOAA 8*, was launched in March 1983, as well as the second Soviet COSPAS satellite, and program performance has equaled or exceeded expectations. By late 1983, the program had assisted in saving 120 human lives.

NASA and several companies filed separate petitions with the FCC for developing commercial land-mobile service from satellites to provide telephone service in rural areas, vehicle dispatch and position determination, data transmission, message distribution, and emergency communications.

**Communications Research.** Development of high-risk advanced technology for future communications systems continued in 1983, with emphasis on potential use of multiple-frequency bands to support both government and industry users. NASA concentrated on developing and ground-testing technology for satellites, as industry moved forward in developing its own commercial satellites.

#### **Earth Resources and Environment**

In 1983, Spacelab introduced new capabilities for use of space, and new satellites were added to those

already orbiting the earth to observe its surface; monitor its resources, weather, and geologic hazards; and study the composition and dynamics of its atmosphere.

*Inventorying and Monitoring Earth Resources.* The joint NASA-European Space Agency Spacelab 1—orbiting the earth in the Space Shuttle's cargo bay November 28 to December 8, 1983—took radiometer microwave measurements of the earth and obtained infrared and visible film coverage of specific targets, among its many, multidiscipline experiments. The metric camera returned high-resolution images of many previously unmapped regions of the earth.

The *Landsat 4* satellite, in orbit since July 1982, acquired more than 7,000 scenes of the earth with its new remote sensor, the thematic mapper, by the end of 1983, contributing to the monitoring of earth resources. Although two solar-array panels failed, the remaining two maintained power for the spacecraft and for multispectral-scanner data collection. When power fails on another panel, the satellite is to be moved down to an orbit where the Shuttle can retrieve it. Meanwhile, *Landsat D'* (D prime; to be renamed *Landsat 5* when launched) was readied for March 1984 launch. The National Oceanic and Atmospheric Administration (NOAA) assumed operational responsibility for *Landsat 4* in January and will also operate *Landsat 5* in its land satellite system, distributing images and data to U.S. and international users.

NOAA collected daily satellite data for a global mapped-vegetation index as part of the multiagency AgRISTARS (Agriculture and Resources Inventory Surveys through Aerospace Remote Sensing) program led by the Department of Agriculture. *Landsat* data were particularly useful in estimating acreage for major crops in seven states. AgRISTARS also began evaluating the possible use of data from meteorological satellites for earth observations.

The Department of the Interior used satellite data in developing data bases for mineral resources assessment, soil survey maps, a national water summary, irrigation analysis, and maps of wildland fire fuels, as well as using aerial radar data for energy-resource and mineral research. Both Interior and the Department of Agriculture used *Landsat 4*'s higher-resolution data to classify vegetation, land cover, and land use for inventory, management, and research. *Landsat 4*'s greater spectral sensitivity identified detailed landmarks and resources for improved maps. Aerial photographs also aided land inventory, assessment of wildlife habitats, and monitoring of volcanoes and geologic hazards.

*Monitoring the Seas.* The Navy's *GEOSAT* geodetic and geophysical satellite was prepared for a late 1984 launch to measure the ocean's surface for improving the accuracy of the maritime geoid. Plans went forward for the late 1980s launch of the oceanographic satellite *N-ROSS* (Navy Remote Ocean-Sensing System), which will use technology developed in

NASA's 1978 *Seasat*. The Navy, Air Force, NASA, and NOAA are cooperating in this project to gather oceanographic and atmospheric data for military and civil uses.

#### *Environmental Analysis and Protection*

*Weather Satellite Operations.* Three new meteorological satellites, two for NOAA and one for DoD, were added in 1983 to those already monitoring the earth's environment. The *GOES 6* Geostationary Operational Environmental Satellite, launched in April as the new "GOES-West" weather satellite for NOAA, joined *GOES 5* ("GOES-East") to make full-disk earth pictures every half hour or scan north-south portions at shorter intervals. Radiometric data help provide a three-dimensional structure of atmospheric temperature and humidity; analyzed weather data and forecasts are relayed from a central facility for immediate dissemination to users. *NOAA 8*—the first Advanced Tiros-N "stretched" spacecraft, with expanded capabilities—replaced *NOAA 6* in March, joining *NOAA 7* in NOAA's low-earth-orbit operational weather system.

DoD's second block 5D-2 DMSP satellite was launched in November 1983, following *DMSP F-6* launched in November 1982, in the Defense Meteorological Satellite Program to provide high-resolution visible and infrared imagery of clouds, soundings of atmospheric moisture and temperature, and monitoring of the ionosphere for the Army, Air Force, Navy, and Marine Corps. Each satellite provides full earth coverage twice a day, and weather forecasts are available 24 hours a day for all areas of the globe.

High-resolution, 15-minute-interval GOES imagery gave weather support to Space Shuttle missions during the year, and GOES information aided monitoring and warning of the unusually large number of tropical cyclones in the Pacific Ocean from November 1982 to May 1983, as well as hurricanes in the Atlantic. Satellite data assisted interagency monitoring of the snowmelt that flooded Salt Lake City and the Colorado basin in 1983 and warned of flooding from river ice in Alaska, of forest fires in Brazil, and of eruptions of volcanoes elsewhere.

Customers for weather satellite photos continued to increase; weather facsimile broadcast schedules and radiofax services expanded. The GOES Data Collection System relayed almost immediate environmental data to 78 national and some 950 international users. Data-collection platforms in the system were expected to reach 5,000 platforms during 1984.

*Atmospheric Research.* Spacelab 1's 71 experiments on the STS 9 Shuttle mission included investigations of space plasma physics and atmospheric physics. Preliminary returns at the end of the year indicated that most of the experiments were highly successful, including first observations of carbon dioxide in the thermosphere and of water and methane in the



mesosphere. The first six-member Shuttle crew—including four science specialists—was able to conduct scientific operations around the clock. DoD's Space Test Program (STP) flew a get-away-special experiment on STS 7 in June that obtained earth-background radiation data. Another STP mission, launched on a Scout vehicle in June, studied effects of ionospheric plasma on radio propagation.

Work continued on the Active Magnetospheric Particle Trace Experiment (AMPTE), a three-spacecraft, NASA-German-United Kingdom mission scheduled for a first launch in 1984. Two new programs began: The NASA-Italian Tethered Satellite System (TSS), to be deployed from the Shuttle on a tether up to 100 km long, will study the space plasma surrounding the earth and the atmosphere below the Shuttle. *CRRES*, the Combined Release and Radiation Effects Satellite to be launched from the Shuttle in a joint NASA-USAF project, will release chemicals at high altitudes to study upper atmosphere motion and magnetospheric electric fields. Development also continued on instruments for the proposed Upper Atmospheric Research Satellite (*UARS*) to study composition and dynamics of the stratosphere.

The Department of Commerce's National Geophysical Data Center compared data from U.S., European, and Japanese satellites with ground-based data for magnetic, upper atmospheric, and ionospheric studies. The National Center for Atmospheric Research, supported by the National Science Foundation, found that termites are a major source of the world's supply of methane gas. Methane is a trace gas, but contributes to the "greenhouse effect" of the atmosphere.

The Environmental Protection Agency continued to cooperate with NASA in studies of atmospheric processes.

### *Materials Processing*

Operational Space Shuttle missions expanded studies of materials processing in space. The seventh Shuttle flight, in June, carried NASA and West German studies of the stability of mercury-gallium dispersions and cesium-chloride solidification phenomena. McDonnell Douglas Corporation's continuous-flow electrophoresis system was flown again in 1983 to experiment with separating biological materials to produce pure pharmaceutical fluids in the low gravity of space. As part of the joint-endueavor agreement with McDonnell Douglas, NASA made eight electrophoresis separations in the Shuttle to compare with control experiments on the ground. The monodisperse-latex reactor was also reflown, to produce high-quality beads of latex for precise calibrations and medical research. On Spacelab 1's flight, silicon crystals for electric components were grown three to four times larger than on earth, and two human pro-

teins for pharmaceutical use were grown 27 to 1,000 times larger.

## **Space Science**

Scientific satellites and space probes, Space Shuttle science specialists and experiments, suborbital vehicles, and ground-based observations made discoveries and obtained new data in 1983 to contribute to our knowledge of the origin and evolution of life, the earth, the solar system, and the universe. Medical and biological studies in space also continued.

### *Sun-Earth Studies*

*ISEE 3*, the International Sun-Earth Explorer launched in 1978, completed its studies of the solar wind and was moved into an orbit swinging through the earth's magnetic tail, behind the moon, and on toward a September 1985 rendezvous with Comet Giacobini-Zinner. The spacecraft obtained the first field and particle measurements made from inside the magnetic tail, contributing to understanding of the flow of the sun's energy and its effects on the earth. *ISEE 3* was renamed International Cometary Explorer (*ICE*), leaving earth orbit December 22, 1983, on a close lunar swingby and toward the comet's path.

NASA, the European Space Agency, and Japan began planning for a 1989-1992 series of international missions to study solar-terrestrial physics, integrating measurements requiring simultaneous monitoring of the plasma source and storage regions as well as solar seismology and corona.

### *Study of the Planets*

*Pioneer 10*, still returning data after its 1972 launch across the asteroid belt and past Jupiter and its radiation belts and moons, left the solar system June 13, 1983. It will continue to return data for several years, seeking the heliopause, the boundary between the region controlling the sun's magnetic field and true interstellar space.

*Pioneer-Venus 1*, studying the atmosphere of Venus since 1978, found evidence of possible volcanic activity on that planet. *Voyager 1* and 2 continued journeys begun in 1977, sending back data on the interplanetary medium after earlier dramatic images and data on Jupiter, Saturn, and their moons. *Voyager 2* was scheduled for 1986 and 1989 meetings with Uranus and Neptune, while *Voyager 1* continued toward the orbit of Uranus on its way out of the solar system. Smithsonian Astrophysical Observatory scientists analyzing data from *Voyager 2* discovered a volcanic eruption on Jupiter's satellite Europa and evidence of electrostatic discharges in Saturn's B ring.

Plans went forward for a 1986 launch of the *Galileo* mission in cooperation with West Germany. The

spacecraft, to reach Jupiter in 1988, will release an atmospheric probe into Jupiter's atmosphere, while the spacecraft itself orbits the planet for 20 months investigating the moons and magnetosphere.

#### *Study of the Universe*

*IRAS*, the Infrared Astronomical Satellite launched in January 1983, observed the formation of stars throughout our galaxy, discovered five comets and many asteroids, found dust clouds above and below the sun, and observed possible beginnings of the formation of planetary systems around Vega and several other stars. Designed by U.S., Netherlands, and United Kingdom astronomers, *IRAS* surveyed the entire sky, covering almost three-fourths of it twice and cataloging some 225,000 infrared sources including 20,000 galaxies and numerous newly observed phenomena. Spacelab 1's ultraviolet telescope orbited on the Shuttle detected many stars not seen before.

Manufacturing of major components for the *Hubble Space Telescope* was completed during the year, after earlier technical and cost difficulties. Assembly and testing began for this spaceborne astronomical observatory to be launched by NASA in 1986 for use by the international astronomy community.

Analysis of data received from the *HEAO 2* satellite in past years continued at the Smithsonian Observatory in 1983 and resulted in detection of x-rays from a radio pulsar spinning about 20 times faster than the most rapid pulsar known until then. The data were also used to develop an x-ray classification scheme for clusters of galaxies, with the conclusion that many clusters are dynamically young. Analysis of observations by the International Ultraviolet Explorer (*IUE*; in orbit since January 1978) revealed the first ultraviolet flare recorded on a giant star.

#### *Research from the Ground*

Infrared observations from the ground, aircraft, and high-altitude balloons included imaging and spectroscopy of astronomical objects. National Science Foundation-supported scientists using optical telescopes witnessed the birth of a star and discovered what may be the first black hole (superdense space object) outside the Milky Way. Others found the first large nebula seen outside any galaxy.

Thirty sounding rockets launched in Peru studied ionospheric and atmospheric phenomena peculiar to the geomagnetic equator. An international balloon series in July compared ozone measuring devices. Analyses of the data continued at the end of the year.

NASA transferred mobile very-long-baseline-interferometry (VLBI) technology to NOAA's National Geodetic Service for establishing the National Crustal Motion Network to monitor the earth's rotation and polar motion. The networks yield data on the dynamic behavior of the earth, including earthquakes.

#### *Life Sciences*

NASA made progress in studying space adaptation, cardiovascular deconditioning, and loss of mineral content in bones during manned spaceflight, as well as the response of living organisms to gravity. Spacelab 1 flew 15 life sciences experiments, and results will be analyzed during 1984.

Achievements in NASA's biological research included detection of genetic-code precursor molecules in meteorites and primitive earth simulations, identification of biological sources of methane gas, and assessment of methane on global atmospheric chemistry.

### **Space Transportation**

Extensive U.S. research continued to develop new space transportation systems and improve operation, economy, and versatility of existing systems.

#### *Space Transportation System (STS)*

Four operational launches of the Space Shuttle and the first launch of its reusable research laboratory Spacelab continued to demonstrate the versatility of the Shuttle for carrying personnel, equipment, and scientific and commercial payloads into space and back, as well as for launching satellites into orbit. A second orbiter was added to the STS fleet and a third delivered for preparation.

*Space Shuttle.* The first flight of the year was also the first flight of the second operational orbiter, *Challenger*. Carrying a crew of four into orbit in April, STS 6 deployed *TDRS 1*, the first spacecraft in NASA's Tracking and Data Relay System. Two astronauts tested new tools and techniques in extravehicular activity in the cargo bay, and experiments tested an electrophoresis system, produced monodisperse latex spheres, and studied lightning, in addition to commercial and Air Force get-away-special experiments.

STS 7 in June, *Challenger's* second mission, carried a crew of five, including the first U.S. woman astronaut in space; deployed and retrieved the German-built, free-flying Shuttle Pallet Satellite *SPAS* that carried a number of scientific experiments; launched communications satellite *Anik C-2* for Canada and *Palapa B-1* for Indonesia; and carried materials processing experiments and seven get-away specials. Launched in August, STS 8, *Challenger's* third mission, also carried a five-member crew, including the first black astronaut. It deployed *Insat 1-B* for India, exercised the Canadian-built remote manipulator arm with its most massive load to date, and tested effects of the space environment on human beings and materials.

The orbiter *Columbia* flew STS 9, launched in November carrying Spacelab on its first voyage. The mission conducted 71 experiments in 5 disciplines, with a European Space Agency payload specialist from

West Germany on board and participation of more than 100 investigators in 14 countries. The six-member crew was the largest launched to date and the 10-day mission the longest Shuttle flight.

The third orbiter, *Discovery*, was delivered for preparation for its first mission, planned for 1984. Delivery of the fourth, *Atlantis*, was scheduled for late 1984.

*Spacelab*. Spacelab 1, developed and funded by 10 nations of the European Space Agency (ESA) over 10 years and carried in the STS 9 cargo bay November 28 through December 8, provided a pressurized environment for experimenters and experiments, as well as a pallet for instruments exposed directly to space. Payload weight was shared equally by NASA and ESA. The laboratory permits scientists, for the first time, to fly in space without long and intensive astronaut training. During the mission, scientists from a number of countries communicated from the ground directly with the orbiting crew performing their experiments in astronomy, solar physics, atmospheric earth observations, life sciences, and material sciences.

*Shuttle Upper Stages*. NASA negotiated contracts for Centaur upper stages for *Galileo* and International Solar Polar (*ISPM*) missions scheduled for launch in 1986. A joint NASA-DoD program will develop two configurations of the stage for the Shuttle: Centaur G for common use and a stretched Centaur G for the two interplanetary missions.

The DoD-developed inertial upper stage (IUS) began service with the Shuttle to boost payloads to higher orbits. On the first use (on STS 6), a gimbal mechanism in the IUS second-stage motor malfunctioned, but the *TDRS 1* satellite, launched into elliptical orbit, was eventually maneuvered in a series of 39 firings of the satellite thrusters into operational geosynchronous orbit. *TDRS 1* supported communications for Shuttle missions 8 and 9 and relayed volumes of data for Spacelab 1. IUS flights were expected to resume in late 1984 after motor correction.

The commercially developed payload assist module, PAM-D, launched nine satellites during 1983, three from the Shuttle in orbit and six from expendable launch vehicles. NASA signed an agreement for commercial development of a larger upper stage, the transfer-orbit stage (TOS).

*Facilities*. DoD essentially completed construction of the major Shuttle launch and landing facilities at Vandenberg Air Force Base in California, for launches into polar orbit. Construction began in May on DoD's Consolidated Space Operations Center near Colorado Springs, with completion planned for 1985. Two major elements—the Satellite Operation Complex and the Shuttle Operations and Planning Complex—will provide a secure environment and adequate capacity for expected Shuttle missions and backup for satellite and Shuttle control.

*Advanced Programs*. Contract studies completed by eight companies in 1983 for a potential Space Station recommended a manned base and unmanned platform in low earth orbit, an Orbital Maneuvering Vehicle, and a second unmanned platform for earth observations in a near-polar orbit, to be serviced by the Space Shuttle. A NASA Concept Development Group formed in 1983 to integrate the study recommendations into a number of concepts anticipated a station with living quarters for a crew of six to eight, but designed for evolutionary growth in size and capability.

Concept definition studies were completed for the Orbital Maneuvering Vehicle (OMV) as a proposed evolutionary capability growing from the Shuttle-based placement and retrieval of spacecraft. A commercial project of NASA with Fairchild Industries defined *Leasecraft* as part of the Space Transportation System. *Leasecraft* would be an unmanned, free-flying platform for launch from the Shuttle in 1987. The Shuttle would later rendezvous with the platform to service or exchange commercial and government payload modules.

DoD's Space Test Program planned to fly 5 experiments among the 57 to be carried on the first mission of NASA's Long-Duration Exposure Facility (*LDEF*), to be deployed into orbit from STS 13 in April 1984 and retrieved by another Shuttle flight in 1985.

### *Expendable Launch Vehicles*

The year again set a perfect launch record for expendable launch vehicles—the seventh year for NASA, which launched 11 satellites on 11 vehicles (in addition to 5 satellites put into orbit from Space Shuttle flights). All but 1 of NASA's launches were reimbursable operations for commercial, international, or other U.S. government users. DoD launched 11 payloads on 7 launch vehicles, including 1 triple and 2 dual launches, in addition to 1 launched for DoD by NASA. (See table of 1983 launches in appendix A-3 and launch vehicles in appendix D.)

DoD began termination of Titan III production, and both NASA and DoD began activities to facilitate commercial operation of expendable vehicles, following the President's May 1983 policy statement endorsing commercial operation by the private sector (see appendix F).

## **Aeronautics**

### *Improvement of Operational Systems*

Both civilian and military programs made advances in aeronautical development in 1983, to improve operational U.S. airborne systems and national airways.

**BOMBER AIRCRAFT.** DoD's first production B-1B multirole bomber, a modernized derivative of the B-1A, is scheduled to roll out in October 1984. A fleet of 100 aircraft is planned to be fully operational by 1988. Testing of a B-1B prototype continued in 1983 as part of the President's strategic program announced in 1981. The aircraft, with newly developed offensive systems and increased takeoff weight, will provide transition to a mixed force to serve through the 1990s and into the next century.

**FIGHTER AIRCRAFT.** In March 1983, the Secretary of Defense approved production of the F/A-18 Hornet naval strike fighter, a multimission, twin-engine, mid-wing, tactical aircraft to replace the Navy's F-4 and A-7. The Air Force began two projects in the Advanced Tactical Fighter Technologies program—an advanced fighter engine and a new airframe design.

**TRANSPORT AIRCRAFT.** DoD completed development and testing of a modified wing for the C-5A inter-theater cargo aircraft to permit full mission capability and to extend its service life to 30,000 flight hours. A new program was begun using the same basic design for the C-5B. Testing and analysis continued toward full-scale development in 1985 of the C-17 for transporting large equipment over intercontinental distances. Results of analyses thus far have met or exceeded specifications.

**REMOTELY PILOTED VEHICLE (RPV).** In the Army's RPV program, integration of the data link and television sensor was tested, software certification was completed, and flight tests resumed. The small unmanned air vehicle will carry out target-acquisition, laser-designation, aerial-reconnaissance, and artillery-adjustment missions.

**HELICOPTERS.** The Air Force restructured its night and adverse-weather HH-60D Night Hawk program from \$5 billion for 243 aircraft to \$2.8 billion for 155 aircraft for combat rescue and special operations. The first production CH-47D medium-lift helicopter was delivered in an Army modernization program, with 436 aircraft eventually to be modified for the improved performance and reliability demonstrated by prototypes. A production prototype of a version of the H-53 helicopter, the MH-53E, was fabricated in a Navy development program, for towing equipment to counter large, sophisticated mines that could paralyze shipping. Flight testing began in the fall. The Army's first production AH-64 Apache antitank helicopter—to be armed with laser-guided missiles—rolled off the assembly line in September, two months ahead of schedule. Flight tests began, for first delivery in early 1984.

**V/STOL AND V/TOL.** Preliminary design began in April 1983 to define full-scale development of the joint services advanced vertical-lift aircraft (JVX), a self-deployable, multimission V/STOL for the 1990s and beyond. The JVX is planned to provide assault vertical

lift for the Marine Corps, combat search and rescue for the Navy, and special operations for the Air Force. Flight testing was two-thirds complete on four full-scale development AV-8B vertical or short takeoff and landing aircraft for the Marine Corps. The improved, vectored-thrust aircraft will provide twice the range or payload performance of the AV-8A.

**CRUISE MISSILES.** The Air Force completed development and initial flight testing of the ground-launched cruise missile (GLCM) in July 1983 and reached initial operational capability in December. Development and operational testing was conducted on the antiship and land-attack Tomahawk missiles (TASM and TLAM), with TASM fleet capability achieved on two ships.

**ANTISATELLITE SYSTEM.** DoD development of an antisatellite system to deter and counter hostile satellite threats focused on a miniature vehicle interceptor and a two-stage missile to be launched from F-15 aircraft.

**Airway Systems.** The Federal Aviation Administration (FAA) of the Department of Transportation, responsible for the nation's airways, conducts development programs to improve the safety of airways and airports, increase efficiency of air navigation and traffic control, and ensure the compatibility of air operations with the environment. Many programs are conducted with other agencies, including NASA, DoD, and the Department of Commerce.

**AIR SAFETY.** DoD, NASA, and FAA continued studies of weather hazards to aviation, including lightning, wind shear, and turbulence. The National Research Council also studied the wind-shear data collected, and NASA used a jet transport simulator to assist FAA and airlines in training pilots to meet hazards. Flight research investigated ways to combat atmospheric icing of aircraft, as well as ways to aid in stopping aircraft on wet and snowy runways.

FAA and NASA continued to develop lightweight fire-resistant materials to reduce the threat of fire in aircraft cabins. Fire-blocking layered seat cushions, tested in postcrash fire conditions, increased occupant escape time by one minute, and new wall panels being developed promised further increased time. FAA issued a notice of proposed rulemaking for fitting aircraft seats with the layered materials and another for marking escape paths for passengers.

FAA tests with retired aircraft demonstrated the ability of the antimisting fuel additive FM-9 to reduce the severity of postcrash fires. A remotely controlled crash of a jet transport scheduled for 1984 will test the antimisting-kerosene safety fuel, measure structural loads, and evaluate metallic and composite structures.

FAA research into devices to detect explosives in aircraft baggage and cargo found x-ray absorption and thermal-neutron activation devices had potential for meeting requirements, while additional research was needed for evaluation of a nuclear magnetic-resonance device and development of a walk-by detector. The



agency explored construction of runway pavements from indigenous materials at remote sites and began research to develop a mixed rubber and asphalt concrete that would recycle discarded rubber tires.

**AIR TRAFFIC CONTROL.** FAA updated its National Airspace System Plan for modernizing its navigation and traffic control system to meet traffic demands of the next two decades. The agency awarded design contracts in 1983 for a new computer to meet needs of the en route air traffic control system into the early 1990s and planned a total new automation system for needs beyond that time. Upgrading proceeded for other automation systems, navigation aids, instrument landing systems, radar surveillance, and integrated communications.

### *Aeronautical Research*

NASA and DoD continued to make advances in aeronautical research and development in 1983, to maintain U.S. leadership in world air transportation and military aeronautics.

**FACILITIES.** NASA began operation of the Man-Vehicle Systems Research Facility, a sophisticated full-mission, full-system flight simulator at Ames Research Center that will make major contributions to cockpit design and use for future generations of aircraft. Langley Research Center began operation of its Avionics Integration Research Laboratory (AIRLAB) and the National Transonic Facility, a cryogenically cooled wind tunnel. Lewis Research Center completed a laboratory for basic combustion research.

NASA's new computer science applications program opened the Research Institute for Advanced Computer Science (RIACS) at Ames, awarded a grant to the Massachusetts Institute of Technology to develop a center for aerospace computing, and sought to develop core skills within the agency as well as pioneering applications of computers to aerospace problems.

**ENGINES.** New NASA methods in compressor-blade design permitted increased operating pressure with fewer blades, promising significantly reduced development time and cost for advanced engine designs. In NASA's Energy-Efficient Program, an engine core integrated with low-spool components in a test vehicle showed excellent starting and transient capabilities, improved thrust, and greater efficiency with less fuel. A new manufacturing process produced silicon carbide crystals for electronic instrumentation above 500°C, for use in hot sections of gas turbines and other projects requiring high-temperature electronic components.

A joint USAF-NASA program demonstrated a variable-cycle engine, transonic and supersonic compressor system, and advanced superalloys in augmented flameholders, as well as verifying the life of single-crystal turbine blades. Another USAF-NASA program proceeded with competitive development of two prototype demonstrators of a multiapplication core engine, the joint advanced fighter engine (JAFE).

**AERODYNAMICS AND CONTROL SYSTEMS.** A NASA program studying low-drag laminar flow over wings demonstrated a 20-percent reduction in turbulent air friction over aircraft wing surfaces. Research using new materials, fabrication methods, and analysis and design techniques indicated that practical systems for control of laminar flow may be developed. NASA began tests of two leading-edge test articles installed on a JetStar aircraft to focus on the most difficult problems in laminar flow.

In the joint USAF-NASA advanced fighter technology integration (AFTI) program, an F-16 aircraft incorporating digital fly-by-wire control and canard surfaces completed flight tests of the digital flight-control system. Modifications of the aircraft were begun for further tests in 1984. The advanced system was to be integrated with a fire control system and new infrared sensor and tracker for highly accurate maneuvering at very low altitude to demonstrate technology to improve future fighter aircraft. During the year, mission-adaptive wings (MAWs) were delivered for installation and checkout on the AFTI/F-111 for 1984 flight research. These are supercritical wings using smooth leading-edge and trailing-edge devices that can assume many shapes for optimum performance.

The first X-29 experimental forward-swept-wing aircraft began extensive ground testing for its first flight in mid-1984, in the joint DARPA-USAF-NASA program to develop integrated, advanced aerodynamic, structural, and flight control technology. Wind-tunnel tests at Ames and Langley obtained aerodynamic and structural data on the airframe, and Dryden Flight Research Facility conducted piloted simulation tests.

**MATERIALS AND STRUCTURES.** Fabrication of the static test airframe and the flight test vehicle began in DoD's Advanced Composite Airframe Program (ACAP) applying advanced materials to helicopter structures. Static and dynamic, and then flight, tests were to begin in 1984. NASA studied new powder-aluminum alloys that showed higher strength, lower density, and greater temperature capability for more efficient airframes. A Navy-NASA study investigated lightweight graphite-polyimide composites for gas-turbine engines, successfully testing a new outer fan duct.

**ROTOR RESEARCH.** Modification and subsystem fabrication began for the DARPA-NASA X-wing rotor flight investigation. The X-wing concept combines vertical lifting efficiency of a helicopter with the speed, range, and altitude of a transonic fixed-wing aircraft. When aloft, the rotating rigid rotor will be stopped to convert to a fixed-wing configuration in forward flight. Flight testing of the concept on the rotor systems research aircraft (RSRA) is planned in 1985. NASA delivered one RSRA to the contractor for

modification and ferried the other to Dryden for tests as a fixed-wing aircraft (without the S-61 rotor).

Flight and ground tests on the NASA-Army XV-15 tilt-rotor research aircraft continued to add to the technology base for the proposed DoD joint vertical-lift aircraft (JVX). Fabrication of advanced rotor blades was completed for testing. The Navy, Marine Corps, and Army evaluated the XV-15 for a number of operational uses. Test aircraft were modified, and flight evaluations expanded the flight envelope.

The Army began the Advanced Rotorcraft Technology Integration (ARTI) program in support of 1987 development of a family of light helicopters (LXH). The ARTI program will study design and specifications for advanced, integrated, and automated cockpit and associated electronics for improved communications, navigation, weapon management, and

pilot workload. An advanced digital-optical control system (ADOCS)—also to improve handling and reduce pilot work load—completed 80 percent of the detailed design phase, with flight testing scheduled for 1984.

**POWERED LIFT.** Models of two single-engine supersonic short-takeoff and vertical-landing fighter attack aircraft were designed in a NASA program. One, using an ejector augmentor, began wind-tunnel testing. The other, based on plenum burning, will be tested in 1984.

**AVIONICS.** A joint Air Force-Army advanced development contract was awarded in 1983 for multiband digital avionics for the Integrated Communication, Navigation, Identification Avionics program. Testing also was completed on an inertial navigation system for Army helicopters.

# National Aeronautics and Space Administration

The National Aeronautics and Space Administration (NASA), established in 1958, is responsible for planning, directing, and conducting civil research and development in space and aeronautics. A number of other federal, state, local, and foreign governments share in these activities, and collaboration with industry is expanding, with increasing emphasis on the commercial use of space. The Department of Defense and NASA cooperate extensively, since DoD is responsible for the nation's military space and aeronautics programs.

NASA's long-standing goals in space have been to develop technology to make space operations more effective; to enlarge the range of practical applications of space technology and data; and to make scientific investigations of the earth and its immediate surroundings, the natural bodies in our solar system, and the origin and evolution and physical processes of the universe. In aeronautics, the goal has been to improve the aerodynamics, structures, engines, and overall performance of aircraft, to make them more efficient, more compatible with the environment, and safer.

On October 1, 1983, President Reagan issued a proclamation honoring the 25th anniversary of the founding of NASA, citing its record of "scientific and technical achievements which has established the United States as the world leader in aerospace research and development."

## Applications to the Earth

Research in 1983—supported by the Space Shuttle and earth-orbiting satellites—continued to improve and increase the applications of space technology for man's use on earth. Development of high-risk advanced technology continued, with the aim of providing advanced communications systems for the future, while search-and-rescue demonstration satellites helped save human lives on vessels and aircraft in distress. New orbiting sensors on board satellites studied the earth's atmosphere and the environment and monitored the earth's weather and resources. Investigations expanded in the use of the low gravity of space to improve production of materials for medical and industrial needs.

## Communications

*Advanced Research and Development.* The goal of NASA's satellite communications R&D program is to develop the advanced communications technology that has the potential for application in multiple-frequency bands to support a wide range of future communications systems for NASA, other government agencies, and industry.

Research continued in support of an advanced communications satellite, operating in the 30-20 GHz frequency band. NASA's program focused on developing and ground-testing the technology for advanced satellites, in view of industry programs now developing commercial satellites.

*Search and Rescue.* By late 1983, 120 human lives had been saved in separate incidents in Canada, the United States, and Western Europe with the assistance of the COSPAS-SARSAT satellite-aided search-and-rescue program, and the number continued to grow. This international cooperative program demonstrates satellite technology to detect and locate aircraft or vessels in distress. The United States, Canada, France, and the Soviet Union developed the system; Norway, The United Kingdom, and Sweden are also participating.

The first satellite within the framework of the joint COSPAS-SARSAT project was launched by the Soviet Union on June 30, 1982. During March 1983, the second COSPAS satellite and the first SARSAT-equipped U.S. satellite, *NOAA 8*, were launched. All were operating well at the end of the year, providing three satellites for the balance of the demonstration phase of the program. Ground stations and control centers are in regular operation in the United States, Canada, France, the USSR, Norway, and the United Kingdom. The performance of the combined satellite and ground system has equaled or exceeded expectations for sensitivity, accuracy, and ground coverage.

## Environmental Observations

New sensors on the Space Shuttle and free-flying satellites returned increasingly refined data on the earth's atmosphere and environment.

*Upper Atmosphere.* Spacelab 1, the first flight of the joint NASA-ESA (European Space Agency) Shuttle-

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borne laboratory built by ESA—was launched on Space Transportation System mission 9 (STS 9) in November. It achieved a number of firsts and included among its 71 experiments 11 investigations in space plasma physics, atmospheric physics, and earth observations. While analysis of the data has not yet been completed, preliminary returns indicate that most of the experiments were highly successful. Preliminary results include the first observation of carbon dioxide in the thermosphere and of water and methane in the mesosphere, coverage of targets by the metric camera using visible and infrared film, and radiometer microwave measurements of the earth. The flight of a six-member crew, for the first time, permitted scientific operations around the clock.

The Active Magnetospheric Particle Tracer Explorers (AMPTE satellites) continued on schedule for launch in 1984, in a three-spacecraft cooperative mission among NASA, the Max-Planck Institute in West Germany, and the Rutherford Appleton Laboratory in the United Kingdom.

Two new programs were started in 1983 for the Tethered Satellite System (TSS) payload and the Combined Release and Radiation Effects Satellite (CRRES). TSS, a joint project between NASA and the Italian government, is to deploy a payload at the end of a long tether from the Space Shuttle to study the space plasma surrounding the earth and the atmosphere below the Shuttle. CRRES, a joint NASA-Air Force satellite, will release chemicals at high altitudes to study the motions of upper atmosphere and the electric fields in the magnetosphere.

In addition, development continued on instruments for a proposed Upper Atmospheric Research Satellite (UARS), for launch from the Shuttle in the 1980s to make integrated global measurements of the composition and dynamics of the stratosphere.

*Lower Atmosphere.* The Geostationary Operational Environmental Satellite *GOES 6* was launched April 28, 1983, for the National Oceanic and Atmospheric Administration (NOAA) to replace the NOAA "GOES-West" satellite at 135° west longitude. *GOES 6* joined *GOES 5*, the GOES-East satellite at 75° west longitude, to complete NOAA's two-satellite geosynchronous operational system. *GOES 6*, equivalent to earlier satellites in this series, can make full-disk earth pictures in the visible and infrared spectrum every half hour or scan any north-to-south portion of the earth's disk in a proportionately shorter interval. Radiometric data will help determine the three-dimensional structure of atmospheric temperature and humidity. A satellite weather-facsimile system will relay analyzed weather data and forecasts from a central facility to small operational units for immediate dissemination to users. A number of design changes in *GOES 6* increased redundancy and should prolong sensor lifetimes.

*NOAA 8* (NOAA-E before launch)—the first of the Advanced Tiros-N spacecraft—was launched into an early morning sun-synchronous orbit on March 28, 1983, replacing *NOAA 6* as NOAA's operational morning spacecraft and joining *NOAA 7*, to complete the two-satellite low-earth-orbiting operational system. Advanced Tiros-N spacecraft are "stretched" versions of the original Tiros-N series and expand capabilities for additional operational R&D instruments. *NOAA 8* is the first to carry instruments provided by Canada and France for the cooperative SARSAT project. Future sensors will measure amounts and distributions of atmospheric ozone, as well as the earth's radiation budget.

#### *Resource Observations*

*Landsat 4*, launched into orbit July 16, 1982, to monitor earth resources and to test its new remote sensor, had acquired more than 7,000 thematic mapper scenes of the earth by the end of 1983. Limited tests run through the preoperational Tracking and Data Relay Satellite System (TDRSS) showed that this data link can transmit high-quality thematic mapper scenes. Despite a failure of two of *Landsat 4*'s four solar-array panels, sufficient power was available to maintain all spacecraft subsystems and to acquire multispectral scanner data. *Landsat 4* will be moved down into an orbit where the Shuttle can retrieve it when power begins to fail on either of the two remaining solar-array panels. The Landsat-D' (D prime) spacecraft was being reintegrated and tested for launch readiness by March 1, 1984.

#### *Materials Processing in Space*

In 1983, NASA expanded its orbital-flight investigations of materials processing in space, taking advantage of the Space Shuttle's operational missions. On STS 7 in June, the materials experiments assembly (MEA) flew in OSTA 2, a cooperative payload of NASA and the West German Federal Ministry for Research and Technology (BMFT). Three BMFT-sponsored experiments flew in get-away-special canisters: two studies of the stability of mercury-gallium dispersions and a study of cesium-chloride solidification phenomena. The experiments operated as planned. The MEA, an autonomous battery-powered system designed to carry rocket-class experimental hardware in the Shuttle cargo bay, carried an isothermal furnace, a gradient furnace, and an acoustical levitational furnace. The MEA will continue to be used for precursor experiments of microgravity phenomena with simple rocket-class hardware. Two Shuttle missions carrying these and other experiments are scheduled for 1984. During 1983, final checkout was made of an experiment designed to grow and monitor tryglycerine sulfate crystals from solution and mercuric oxide from vapor. It was delivered to Kennedy Space



Center for installation in Spacelab 3, to fly in late 1984.

Shuttle mid-deck experiments in 1983 included reflights of McDonnell Douglas Corporation's continuous-flow electrophoresis system (CFES; an experiment to separate biological materials to produce pure pharmaceutical fluids in the low gravity of space) and the monodisperse-latex reactor (MLR; an experiment to produce uniform, high-quality beads of latex in space for precise calibrations and medical research). Following results from the CFES, McDonnell Douglas plans to purify sufficient quantities of its "proprietary" protein mixture in 1984 for clinical studies of the commercial practicality of separating materials in space that are difficult to separate on the earth. As part of the joint-endavor agreement with the corporation, NASA performed eight CFES separations on the Shuttle to study generic advantages of the process over control experiments on the ground. Materials separated included polysaccharides, red blood cells, live rat pituitary cells, and live kidney cells. The NASA results were being analyzed at the end of the year.

## Science

During 1983, spacecraft discovered surprising new phenomena as NASA continued investigations into the origin and evolution of the universe and solar system and into the causes and processes of the earth's environment. Space technology and the low gravity of space also were applied to medical and biological studies.

### *Study of the Sun and Its Earth Effects*

International Sun-Earth Explorer *ISEE 3*, launched in 1978, completed its original mission of monitoring the solar wind and was maneuvered into an orbit swinging through the earth's magnetic tail and behind the moon, using the moon's gravity to boost the spacecraft toward rendezvous with a comet. *ISEE 3* obtained the first in situ field and particle measurements in the earth's magnetotail, to give a better understanding of the sun's energy flow and effects on the earth. It was renamed International Cometary Explorer (*ICE*) and on December 22, 1983, left earth orbit at close lunar swingby on a trajectory to encounter Comet Giacobini-Zinner in September 1985.

Also in 1983, NASA, the European Space Agency, and the Japanese Institute of Space and Astronautical Science (ISAS) began planning for an international program in solar-terrestrial physics. The plan is for a series of collaborative missions for 1989-1992 to pursue internationally recognized scientific objectives. The proposed program integrates solar and plasma physics measurements requiring simultaneous monitoring of the plasma source and storage regions as well

as solar seismology and diagnostic measurements of the corona.

### *Study of the Planets*

Plans proceeded toward a May 1986 launch of the *Galileo* mission in cooperation with the republic of West Germany, to reach Jupiter in 1988. The mission will include an atmospheric probe to study the chemical composition of Jupiter's atmosphere. The spacecraft itself will orbit Jupiter for 20 months, studying the planet's satellites and investigating the physical dynamics of its magnetosphere.

On June 13, 1983, *Pioneer 10*, launched in 1972, became the first man-made object to leave the solar system. It was still returning data after its long journey as the first spacecraft to cross the asteroid belt and fly by Jupiter to study and photograph that planet, its radiation belts, and moons. *Pioneer 10* will continue to return data for the next several years, with its immediate mission being the detection of the heliopause, the boundary between the region of space controlling the sun's magnetic field and true interstellar space.

*Pioneer-Venus 1*, observing the atmosphere of Venus since 1978, found evidence of possible volcanic activity on that planet. Its ultraviolet spectrometer detected sulfur dioxide and sulfuric acid haze at the cloud tops, as its radar mapper identified topography resembling terrestrial volcanic regions. Attempts to reestablish communications with Viking Lander 1 on Mars, which had ceased transmissions in late November 1982, ended in 1983. The lander had sent back six years of data and thousands of photos from the surface of that planet. *Voyager 1* and 2, launched in 1977, continued their journeys through the outer solar system, providing data on the interplanetary medium after their earlier spectacular discoveries about Jupiter, Saturn, and the moons of these planets. *Voyager 2* headed toward its January 1986 encounter with Uranus and 1989 meeting with Neptune. *Voyager 1* continued toward the orbit of Uranus on its way out of the solar system.

### *Study of the Universe*

*IRAS*. The Infrared Astronomical Satellite *IRAS*—designed by U.S., Netherlands, and United Kingdom astronomers and launched in January 1983—promises enormous advances in our understanding of the universe. *IRAS* exceeded its requirements for surveying the entire sky. During its 10 months of operation, it surveyed almost three-fourths of the sky twice and made more than 10,000 detailed observations with its cryogenically cooled infrared telescope.

The new sensitivity of *IRAS* permitted exploration of a previously unexplored gap. *IRAS* observed the formation of stars throughout our galaxy, discovered five comets and many asteroids, found dust clouds

above and below the sun, and observed possible beginnings of the formation of planetary systems around Vega and several other stars. Infrared sources catalogued before IRAS numbered about 1,000. The IRAS catalog will contain some 225,000 sources, including 20,000 galaxies and numerous newly observed phenomena.

*Space Telescope.* Scheduled for launch in June 1986, the *Hubble Space Telescope* will become an unprecedented spaceborne astronomical observatory for use by the international astronomy community. The observatory will measure objects from the ultraviolet to the infrared that are appreciably fainter and more distant than those accessible from the ground. After earlier technical difficulties, delays, and cost increases, manufacturing of the major components such as the primary and secondary mirrors has been completed and mainline assembly and testing is beginning. The five basic scientific instruments have been manufactured and are being verified for acceptance. Four of the instruments were developed in the United States and one by the European Space Agency. The five guidance sensors are considered the sixth scientific instrument when operating in the astrometry mode.

#### *Research from the Ground*

Thirty sounding rockets launched in Peru during 1983, in conjunction with ground-based observations, studied ionospheric and atmospheric phenomena peculiar to the geomagnetic equator.

In the United States, NASA-developed, mobile, very-long-baseline interferometry (VLBI) technology was transferred to the National Geodetic Service of NOAA for establishment of the National Crustal Motion Network (NCMN). Fixed VLBI technology developed by NASA was used for the Polar Motion Analysis by Radio Interferometric Systems (Polaris) Network. This network is now being used by NOAA to fulfill its operational responsibility to monitor the earth's rotation rate and polar motion. Data from the networks aid understanding of the effects of the dynamic behavior of the earth, including earthquake mechanisms.

In an international balloon-borne intercomparison of remote-sensing instruments, 14 instruments flown in the fall of 1982 and 17 in the spring of 1983 returned excellent scientific data. Complementary ground and aircraft-based measurements were also made. The nearly simultaneous measurements were taken of a wide variety of atmospheric components that are the key to understanding the chemistry of the stratosphere. Measured species included the hydroxyl radical, nitric acid, nitric oxide, nitrogen dioxide, hydrogen chloride, chloride monoxide, hydrogen fluoride, water vapor, methane, and ozone. The data were being analyzed at the end of the year. In July, an international balloon-borne intercomparison of ozone measuring devices was

also conducted. In situ and remote sensing devices and operational radiosondes returned data for analysis.

NASA has developed a variety of sensor systems in the past to distinguish materials on the earth's surface by measuring the intensity of solar radiation reflected from the surface. During 1983, an entirely new technology was employed to fabricate an advanced airborne sensor, the airborne imaging spectrometer (AIS), which could measure surface radiation simultaneously in more than 100 discrete spectral bands. Previously designed systems could make measurements in only 4 to 10 bands. The improved spatial and spectral capabilities of the *Landsat 4* thematic mapper also have yielded major advances in vegetation and geological discrimination, as indicated by analysis of data received from the middle reflective and thermal bands, new to the Landsat series of sensors.

#### *Life Sciences*

The NASA life sciences program seeks to provide a sound scientific and medical basis for productive, safe manned spaceflight and to enhance understanding of biological processes. The success of the program is a key to attaining a permanent manned presence in space and to using the environment of space to study living systems. Major elements of the program include operational medicine, biomedical research, advanced life support systems, gravitational biology, exobiology research, and biospheric research.

Significant progress was made during the year in the operational use of the Space Shuttle and in the study of space adaption and cardiovascular deconditioning. Fifteen of the seventy-one experiments flown on Spacelab 1 on the November Shuttle mission were in life sciences. Data were taken for all the experiments and will be analyzed during the upcoming year. Study continued toward understanding why bones lose mineral content in space and understanding the responses of living organisms to gravity.

Planning continued during 1983 to fly future life science experiments on Spacelab flights.

NASA's biological research program studies the origin of life as influenced by solar system evolution, its role as a modulator of global chemical cycles, and its adaptation to the force of gravity. Significant achievements were made in all areas, including detection of genetic-code precursor molecules in meteorites and primitive earth simulations, identification of biological sources of methane gas and assessment of impact on global atmospheric chemistry, and characterization of plant-cell organelles, which sense and transduce gravity.

#### *Spacelab Flight Program*

Spacelab flight experiments continued to show good results in 1983. The OSTA 2 payload on STS 7 in

June demonstrated and verified a cost-effective NASA-developed carrier system. It also demonstrated the materials-processing multi-use facility—the materials experiment assembly—which permits flight on the Shuttle of previously used materials-processing-experiment hardware developed for suborbital, rocket-launched experiments. Orbital flight extends operational flexibility and length of exposure to microgravity conditions for these investigations (see “Materials Processing in Space” in the Applications section above). Reflights of the assembly in 1984 and 1985 are expected to advance microgravity processing still further.

German Federal Ministry of Research and Technology experiments in OSTA 2 (described in the Materials Processing in Space section) improved operational use of NASA’s low-cost get-away-special arrangement.

Many small payloads and investigations can take advantage of low-cost space available in orbiter mid-deck lockers or compartments, permitting crew attention, and can be scheduled for flight on relatively short notice. The orbiter mid-deck payload program was developed for this class of users and to provide full use of Shuttle capability. Examples of such payloads flown in 1983 include the monodisperse-latex reactor on STS 6 and STS 7 and an experiment on STS 6 to study lighting.

The most significant 1983 advance in the development of operational Shuttle payload systems was the cooperative NASA-ESA Spacelab 1 mission that flew on STS 9 in November. In addition to achieving a significant milestone in a complex cooperative effort with the Europeans, Spacelab provides a flexible, Shuttle-based science research capability for diverse scientific investigations throughout this decade (see also “Upper Atmosphere,” in the Applications section above, as well as the Space Transportation section below). A number of multi-user facilities (life sciences minilab, materials science facility, etc.) and major instruments have been built as a result of Spacelab 1, to accommodate scientific investigations of future Shuttle flights. And processing Spacelab 1 through the centralized experiment and payload integration facility at Kennedy Space Center verified that the KSC facility was ready to support all future Spacelab missions.

The Payload Operations Control Center at Johnson Space Center also was declared operational, supporting Spacelab 1 during flight. The facility verified the payload ground systems that supported Spacelab and was used during simulations to train the ground crews. The Payload Crew Training Complex at Marshall Space Flight Center also trained the flight crews for this first mission in which representatives of the science community flew and operated their own experiments in orbit. Dr. Byron K. Lichtenberg flew as the NASA payload specialist and Dr. Ulf Merbold as the ESA payload specialist.

The final four payload-specialist candidates were selected for the Spacelab 3 mission, scheduled to fly in late 1984. This group of four scientists includes one experiment principal investigator and two co-investigators. Two are fluid-dynamics specialists and two are experts in crystal growth. The designation of prime and backup payload specialists was scheduled for the spring of 1984. Ground operations planning and payload selection continued for Spacelab 2, scheduled to fly in 1985 with experiments in solar physics, high-energy astrophysics, infrared astronomy, plasma physics, life sciences, and space technology.

## Space Transportation

### *Space Shuttle*

In 1983 the Space Shuttle continued to demonstrate its versatility and capability as the world’s most sophisticated launch vehicle—the first reusable earth-to-orbit vehicle for flying personnel, equipment, scientific and commercial payloads, even laboratories, into space and back to earth. With four successful Space Shuttle missions and the first launch of the reusable research facility called Spacelab, 1983 was an important year in NASA’s operation of the nation’s Space Transportation System (STS). A second orbiter was added to the Shuttle fleet and a third was delivered for preparation.

Other Space Shuttle achievements included the first retrieval of a satellite in space, the German-built *SPAS* spacecraft, using the Canadian-built remote manipulator system (RMS); first STS night launch and landing; America’s first extravehicular activity (EVA), or spacewalk, in more than nine years; and launch of five satellites into orbit. The deployment of NASA’s first spacecraft in its Tracking and Data Relay Satellite System (TDRSS) and the launch of three foreign communications satellites and a reusable, free-flying platform again demonstrated the Shuttle’s potential. The missions also showed that, with the advent of the Shuttle, use of space need not depend on sex and age.

### *Space Shuttle Missions*

STS 6, carrying a crew of four into orbit April 4–9, was the first flight of the Space Shuttle program’s second operational orbiter, *Challenger*. The mission placed the *TDRS 1* satellite in orbit with the first deployment from the Shuttle of the Air Force-developed inertial upper stage (IUS) and assistance of the *TDRS 1* on-board attitude control system. Two astronauts worked in EVA in the cargo bay during three orbits, testing new tools and equipment-handling techniques. Three self-contained get-away-special experiments were sponsored by a Japanese newspaper, a South Carolina seed company, and the Air Force Academy. Other ex-

periments on *Challenger's* first flight tested a continuous-flow electrophoresis system (CFES), produced small monodisperse latex spheres, and studied lightning associated with thunderstorms.

The STS 7 flight, from June 18 through June 24—*Challenger's* second mission—carried the Shuttle's first crew of five, the largest number launched into space up to that time. It included the first U.S. woman astronaut. The first full photographs of a Space Shuttle in orbit were taken from the free-flying Shuttle Pallet Satellite *SPAS*, developed by West Germany. A reusable platform for mounting a variety of scientific instruments, *SPAS* was deployed and retrieved by the remote manipulator system (or arm). *SPAS* was the first Shuttle cargo commercially financed by a European company, Messerschmitt-Boelkow-Blohm. This pallet-style satellite carried a number of scientific experiments sponsored by the German Ministry for Research and Technology and the European Space Agency (ESA). An example was the German government-sponsored remote-sensing device, the modular optoelectronic multispectral scanner (MOMS) that observed the earth from *SPAS*.

Two communications satellites, *Anik C-2* for Canada and *Palapa B-1* for Indonesia, were launched from the Shuttle's cargo bay into geosynchronous orbits. And, along with *SPAS*, *OSTA 2* was carried into orbit and returned to earth in the cargo bay. Remaining fixed in the bay, *OSTA 2* carried four instrument packages developed jointly by the United States and the Federal Republic of Germany for materials processing experiments to test the potential for mixing, melting, or crystallizing substances such as metal alloys and glass in the weightless vacuum of space.

The STS 7 mission also carried, attached to the walls of the *Challenger's* cargo bay, 7 get-away-special canisters with 22 experiments sponsored by high school and university students, a private company, and two government agencies. Two more experiments, also performed on previous Shuttle missions, were carried in *Challenger's* mid-deck cabin, the continuous-flow electrophoresis system and the monodisperse-latex reactor (see "Materials Processing in Space" in the Applications section and "Spacelab Flight Program" in the Space Science section above).

On *Challenger's* third mission into space, August 30 through September 5, the five-member crew of STS 8—including America's first black astronaut and America's oldest astronaut (54)—carried out the first Shuttle-to-ground communications via Tracking and Data Relay Satellite *TDRS 1*, deployed India's *Insat 1-B* satellite into geosynchronous orbit, and exercised the Shuttle's remote manipulator system with its most massive load to date, the payload flight-test article. The crew of STS 8 also tested effects of the space environment on astronauts and man-made materials. *Challenger's* third flight was the first Shuttle launch and landing at night.

The ninth flight of the Space Shuttle, November 28 through December 8, marked the return of the orbiter *Columbia* and the maiden voyage of the Space Transportation System's newest facility, Spacelab, developed by the European Space Agency (see "Spacelab" below). The STS 9 flight was a fulfillment of the most comprehensive multinational space project to date. With an onboard ESA payload specialist, Ulf Merbold of West Germany, and participation of more than 100 investigators from 11 European nations, Canada, Japan, and the United States, the mission conducted 71 experiments in 5 scientific disciplines. For the first time during a spaceflight, principal investigators were able to monitor data directly, as soon as collected, and communicate with the crew—the largest crew (6 members) to date and the longest Shuttle mission (10 days). (Mission results are discussed under "Upper Atmosphere" in the Applications section above.)

#### *Orbiter*

Continued progress was made in 1983 to certify the Space Transportation System orbiter fleet. The second delivered orbiter, *Challenger*, flew three successful missions, and the third orbiter, *Discovery*, was delivered to the Kennedy Space Center for preparation of its first mission in mid-1984. Major structural elements for the fourth, *Atlantis* (OV-104), were delivered to the Rockwell International Palmdale plant during 1983, and mating of wings, payload bay doors, vertical stabilizer, and mid-fuselage was begun. Thermal-protection tile installations began, with nearly 41,000 tiles placed on the vehicle. *Atlantis* is scheduled for delivery in December 1984. The structural spares plan was defined and procurement and fabrication of these orbiter elements began. Several facility support elements for the Space Shuttle were activated to accommodate the program's accelerating flight rate.

#### *Main Engine (SSME)*

The Space Shuttle's three main engines continued to prove an unusual advance in propulsion technology, maintaining a record of successful flight performance during the four 1983 Shuttle missions. With no performance anomalies during the four flights, the main engines demonstrated once again their remarkable reusability. Certification of the main engines at 109 percent of the present rated power level, to full power level (FPL), was completed (see appendix D). The certification process included 400 tests of more than 40,000 seconds of firing operation. During 1983, 4 complete main engine sets were delivered and 36 major components were manufactured.

#### *External Tank (ET)*

The Space Shuttle's external fuel tanks continued to perform well in 1983, and the first lightweight tank



(LWT 1) was flown on the STS 6 mission. A number of design changes had reduced the weight of the tank by some 4,000 kilograms, permitting the Shuttle to carry a heavier payload. This improvement and others such as the reduction of ablator on the external tank and the first use of plasma arc welding brought savings in costs. Thirteen other lightweight tanks were in varying stages of production at the Michoud Assembly Facility at the end of the year.

#### *Solid Rocket Booster (SRB)*

The Shuttle's solid-fueled rocket boosters continued to perform well in 1983's four missions. On each spaceflight, two SRBs burn in parallel with the orbiter's main engines for the initial ascent, before dropping away to be recovered for reuse. Ten rockets, or five flight sets, were delivered in 1983, and a new lightweight case was first flown on STS 6. The first high-performance solid-fueled rocket motor flew on STS 8. Development of a design continued for a new filament-wound case that, when operational, will significantly reduce weight and increase ascent performance. A request for proposals for a new booster-assembly contract was released, and work continued at Kennedy Space Center to expand SRB refurbishment and assembly facilities to permit production of 16 flight sets.

#### *Launch and Landing Operations*

*Challenger's* third mission in 1983 (STS 8) demonstrated that the Space Shuttle can be launched and landed at night. The year also reflected improved efficiency in preparing the Shuttle fleet for flight. Certain flight center contracts were consolidated; approval requirements, detailed instructions, and daily serial work were either simplified or reduced. A single, consolidated, on-site support organization was formed and one consolidated contractor established for all launch and landing operations at both Kennedy and the Vandenberg Air Force Base launch site. The leadtime for the payload integration plan (PIP) was reduced 50 percent. The additional operational experience gathered in 1983 has reduced hardware turnaround time from the 187 working days required between STS 1 and STS 2 to 55 working days between STS 7 and STS 8. Continuous planning and the best use of flight hardware, support equipment, and launch facilities should reduce the turn-around time to 35 working days in early 1985.

#### *Spacelab*

The highly successful Spacelab 1 mission, the largest international cooperative space effort yet undertaken, concluded more than 10 years of intensive work by some 50 industrial firms and 10 nations. Costing the Europeans approximately \$1 billion, the reusable

laboratory—carrying experimenters in a pressurized environment to orbit and back in the Shuttle's cargo bay—was designed, developed, funded, and built by the European Space Agency. Established in 1973 by an international agreement among the United States and Austria, Belgium, Denmark, France, Germany, Italy, The Netherlands, Spain, Switzerland, and United Kingdom, the Spacelab project provided an opportunity on its first mission for scientists worldwide to experiment in space in astronomy and solar physics, space plasma physics, atmospheric physics and earth observation, life sciences, and material sciences.

Spacelab 1 also opened the era of "payload specialists," scientists who are not required to take the normally long and intensive astronaut training in order to participate in Shuttle missions.

STS 9, carrying Spacelab 1 and launched from Kennedy Space Center November 28, operated in a 250-km circular orbit inclined to the equator at 57°. All of the mission objectives of verifying Spacelab's modules were met, and earth-based scientists communicated directly with the orbiting space crew that performed their experiments, collected data immediately, and offered directions for the experiments. The principal investigators worked from the newly activated Payload Operations Control Center (POCC).

Other major activities during 1983 were the staging of Spacelab 2 (SL 2) pallets and the delivery by ESA of nine more experiment racks under the international cooperative agreement. Spacelab 3 integration also began, and hardware was provided to Germany for staging the first Spacelab mission dedicated to European use. In late 1984, NASA will launch the first operational mission of Spacelab, Spacelab 3.

#### *Expendable Launch Vehicles*

In addition to the Space Shuttle launches, NASA launched 11 satellites on 11 expendable launch vehicles, using 8 Deltas, 1 Atlas E/F, 1 Atlas-Centaur, and 1 Scout. The year marked NASA's seventh perfect launch record. The European Space Agency's *EXOSAT* x-ray observatory was carried to a highly elliptical polar orbit by a Delta launch vehicle and at the end of 1983 was still transmitting important data on the x-ray sky. The Delta has been the most widely used and successful launch vehicle for NASA since its initial use in 1960. It has been used in 173 launches with a success rate of 92 percent, and both the Delta and the Atlas-Centaur are under consideration for commercial operations. Following the President's policy statement on May 16, 1983 (see appendix F), NASA is proceeding to facilitate commercial operation of the expendable launch vehicle program. At present NASA is reimbursed for services of expendable vehicles by commercial and foreign users.

Other 1983 payloads launched into orbit on NASA expendable launch vehicles were the NASA-

Netherlands Infrared Astronomy Satellite *IRAS*, *NOAA 8* and *GOES 6* for NOAA, *HILAT* for the Air Force, *Intelsat V F-6* for INTELSAT, *Galaxy 1* and *2* for Hughes Communications, *Telstar 3A* for AT&T, and *RCA-Satcom 1R* and *2R* for RCA—all except *IRAS* reimbursable. (See launch table in appendix A-3 and launch vehicle descriptions in appendix D.)

### *Upper Stages*

NASA negotiated contracts in fiscal 1983 with General Dynamics, Honeywell, Pratt & Whitney, and Teledyne for design, development, and procurement of Centaur upper stages for the *Galileo* and International Solar Polar (*ISPM*) missions scheduled for flight in 1986. The Air Force will share with NASA in designing and developing a common Centaur upper stage. The major activity of 1983 resulted in completion of the Centaur G-Prime preliminary and critical design reviews.

The first inertial upper stage (IUS)—being developed by DoD to extend the reach of the Shuttle into higher orbits—was launched from the Space Shuttle on flight STS 6. Carrying the first satellite in NASA's new Tracking and Data Relay Satellite System (TDRSS), the IUS second stage failed to place the satellite in its final geosynchronous orbit. The satellite and stage tumbled and communications were lost, but *TDRS 1* was eventually stabilized and small onboard thrusters began a three-phase series of 39 maneuvers to place it in the required functional orbit. *TDRS 1* reached its operational orbit June 29. A joint NASA-USAF study team determined the problem was in the gimbal mechanism of the second stage, and motor correction was planned.

These and other upper-stage activities are being supplemented by a number of commercial development projects for NASA. McDonnell Douglas Corporation developed the payload assist module-D (PAM-D), and in 1983 this upper stage launched nine communications satellites, three from the Space Shuttle's cargo bay and six from expendable launch vehicles. NASA and the Orbital Sciences Corporation (OSC) signed a joint agreement for commercial development of a new, larger, upper stage—the transfer-orbit stage (TOS)—in 1983, and development was begun with Martin Marietta Corporation providing technical capability for OSC. The TOS will be designed as a three-axis-stabilized upper stage to be available for use commercially.

### *Advanced Planning*

The advanced development phase of the Tethered Satellite System (TSS), a joint program with Italy, was completed in 1983. TSS, to be jointly developed by NASA and Italy and operated by NASA, will provide a unique capability for conducting experiments in the

upper atmosphere and ionosphere while tethered to the Space Shuttle as its orbiting base.

Concept definition studies for an Orbital Maneuvering Vehicle (OMV) were completed and the planning structured as a proposed evolutionary capability growing from Shuttle-based placement and retrieval of spacecraft for the future Space Station-based operation. Development began toward a flight demonstration of the ability to refuel propellant tanks of an orbiting satellite safely. Hydrazine fuel will be transferred by an astronaut in an extravehicular activity to a simulated satellite, to gain confidence in a new technique that could extend the life of orbiting satellites. Additionally, a prototype-demonstration astronaut suit was constructed that operates at 0.54 atmospheres (8 psi) rather than the present 0.29 (4.3 psi) to permit astronauts to perform EVA without the lengthy pre-breathing of pure oxygen now required to prevent onset of the "bends." Advanced planning studies continued for more powerful boosters using Shuttle components, novel applications of space tethers, Orbital Transfer Vehicles (OTV), and other elements of the anticipated space infrastructure that will be required by the year 2000 along with a Space Station.

### *Space Station Task Force*

The Space Station Task Force continued planning throughout 1983 toward development—pending approval by the Administration and Congress—of a station for low earth orbit in the 1990s. Study contracts awarded to eight aerospace firms in 1982 were completed in 1983. Recommendations from the studies essentially would provide a manned base and unmanned platform in low earth orbit at an inclination of 28.5° to the equator, an Orbital Maneuvering Vehicle operating in tandem with the station, and a second unmanned platform for earth observations in a near-polar orbit, to be serviced by the Spaced Shuttle. Study conclusions indicated that a permanent presence in space would provide advantageous opportunities for science and applications, satellite servicing, commercial applications such as materials processing, and other technology-development investigations.

Designed for evolutionary growth in both size and capabilities, the Space Station would also provide opportunities for international cooperation. A Concept Development Group was formed in 1983 to integrate the eight study teams' recommendations into a number of architectural concepts, which at present indicate living quarters for a crew of six to eight. Two smaller contracts were also awarded in 1983 to explore and define potential commercial uses and improve coordination between the private sector and government organizations.

### *Operation of the Space Transportation System*

Two Space Shuttle orbiters, with solid rocket boosters, external tank, and upper-stage components,

joined by the reusable Spacelab, demonstrated that the Space Transportation System was close to fully operational. The broad applicability of the system is reflected in new opportunities provided to a new class of scientific investigators through the small self-contained payload program, or get-away specials. Some 370 get-away-special experiments were booked in 1983, which will provide new opportunities to investigate a broad range of disciplines for high school and college students, small businesses, foreign governments, and the Department of Defense. Experiments performed in 1983 included investigations with planets, seeds, metals and materials, snow crystals, and ants.

The orbiter's mid-deck also offered new opportunities for space researchers and investigators. Since the STS 6 mission, a number of experiments have been conducted on the mid-deck, and the student Shuttle-involvement project (SSIP) also uses it. Another new program explored in 1983 would permit private citizens to fly on Shuttle missions, possibly as early as 1985. *Leascraft*, a commercial effort of NASA and Fairchild Industries, also was defined in 1983 as part of the Space Transportation System. A \$200-million program plans to develop an unmanned, free-flying platform for launch from the Shuttle in 1987, to offer another low-cost opportunity for commercial and government access to space and its unique environment. The Shuttle is to rendezvous with *Leascraft* to service or exchange payload modules.

## Space Research and Technology

NASA's space research and technology program provides the scientific and technological development enabling the United States to lead in the exploration of the solar system, space applications, and space transportation. The key disciplines include chemical propulsion, computer science and electronics, space communications and sensors, materials and structures, space energy conversion, controls and flight management, and aerothermodynamics. NASA technology also supports research by other government agencies, private industry, and the university community.

### *Research and Technology Programs*

NASA made progress during the year in a number of the key disciplines forming the technology base for its research and technology program.

**Chemical Propulsion.** In 1983, technology for advanced reusable earth-to-orbit propulsion systems continued to focus on understanding and analytically simulating the internal dynamic environment of high-performance staged-combustion rocket engines and on extending the life of critical life-limited components. Rig tests of thermal-barrier coatings applied to turbine blades with a new vacuum plasma-spray technique

showed great promise for eliminating severe spalling previously experienced both in rig tests and in actual Space Shuttle main engine (SSME) testing. Testing of subscale liquid-hydrogen hybrid bearings in a bearing tester and in an actual pump provided the experimental data needed to design and fabricate SSME-class hybrid bearings.

Conceptual design studies of high-performance expander-cycle engines compatible with the requirements of an advanced, spaced-based, aeroassisted orbital transfer vehicle have identified critical technology advances needed to confirm and strengthen concept feasibility. The use of oxygen as a combustor coolant and as a turbine-drive working fluid appears most promising, and work began toward identifying oxygen-compatible materials and establishing oxygen heat-transfer characteristics and cooling capabilities. Techniques for improving component efficiencies, critical to high-combustion-pressure operation are also being developed. These include partial-admission turbines for high efficiency over a broad operating range, and high-performance combustors for enhanced heat transfer through the walls into the turbine-drive working fluid, to improve engine cycle efficiency. The design and fabrication of lightweight, high-expansion-ratio, carbon-carbon nozzles is also being explored.

**Computer Science and Electronics.** The massively parallel processor (MPP), a multibillion-operations-per-second computer consisting of 16,384 processors designed for image processing, was completed and delivered to Goddard Space Flight Center. The MPP will permit modeling of complex space science phenomena not possible with conventional computers. This advanced computer system is typical of the mission-specific computational systems critical to U.S. preeminence in space information science.

Monolithic integrated optical devices are of major interest to remote sensing from space. Electronics research in 1983 demonstrated molecular-beam epitaxy (oriented growth of one crystalline substance on another) for growing new semiconductor devices. An indium arsenide-galium arsenide heterojunction was grown, and its theoretical limits were determined. These devices offer the possibility of new and technologically revolutionary semiconductors for lasers and photoconductors with tailored spectral and electronic properties for advanced sensors.

In initial laboratory tests, a computer program using artificial intelligence techniques to plan automatic spacecraft operations increased productivity of the mission planners by nearly tenfold. The planning system has been tailored for use by the Voyager project during that spacecraft's encounter with the planet Uranus in January 1986. This will be the first use of an expert system in an actual mission environment and will serve as an important test of this technology for the *Galileo* Jupiter probe in 1986 and other science and applications missions.

*Space Communications and Sensors.* A new traveling-wave tube called the tunneladder was operated for the first time in 1983 and produced 400 watts of radiated power at 29 GHz in laboratory tests, making it an excellent candidate for the high-power amplifier for high-data-rate ground terminals in future communications satellite systems.

In sensors, a 5-watt Stirling-cycle refrigerator (65-kelvin temperature) was fabricated with magnetic bearings and operated continuously for 2,000 hours—a much needed breakthrough that can extend the lifetime of cooled spacecraft instruments, limited until now by the amount of stored cryogen carried by the spacecraft.

*Materials and Structures.* The advanced space structures program focused on new structural concepts for more efficient use of the Space Shuttle. To decrease transportation costs to orbit, structural configurations must be packaged efficiently in high-density modules with minimum use of Shuttle volume. Once in orbit, the structural element must be deployed, erected, or assembled with a high degree of reliability. The primary areas being investigated are lightweight structural members, packaging techniques, structurally predictable behavior, and reliable deployment. Analysis methods for advanced structural truss components have been correlated with ground-test results in preparation for in-space flight experiments that will verify concepts and deployment and assembly techniques. Deployment and erectable structures (beams, platforms, and volumes) will be useful for large space structures such as large-aperture antennas or space station modules.

A unique space-environmental-effects facility became operational in 1983 at Langley Research Center. The facility simulates the space environment (electrons, protons, vacuum, ultraviolet) to study effects on materials. Composite materials have been tested and changes in structural properties observed. The facility provides ground-based evaluation of the long-term environmental effects of space on materials and will facilitate development of new materials and protection techniques.

*Space Controls and Human Factors.* Theoretical analyses of distributed control systems for large flexible structures are being developed, including concepts for active shape and vibration control, modeling techniques for control system design, and adaptive systems for increased performance. Initial laboratory tests demonstrated the potential of adaptive control systems for accommodating unanticipated changes in space. An advanced videobased technique for rendezvous and docking was being evaluated in 1983. The human factors program, begun in fiscal 1983, emphasizes man-machine function allocation, teleoperations, extravehicular activity, and crew station design.

*Aerothermodynamics.* Studies of aerodynamic heating to be encountered by orbital transfer vehicles using the

earth's atmosphere for retro-braking on return to low earth orbit have shown the need for precise estimates of non-equilibrium radioactive heating. This component of the heat load on the return vehicle can be as much as five times that due to convection and may alter first concepts of the thermal protection system. The complex chemical reactions are difficult to check experimentally in ground facilities; hence the theoretical approaches are making full use of the latest supercomputer systems.

Space missions in low earth orbit propose the use of large lightweight structural systems that will have minute but important torques and drag forces imposed by the thin atmospheric gases. New analyses have been developed using the so-called Monte Carlo methods that permit estimation of spacecraft reactions to the free molecular flows at orbital altitudes. The newly extended methods can also predict the contaminating effects of control jets on sensitive sensor systems and mirrors carried on the spacecraft.

*Space Energy Programs.* A cooperative three-agency (DOE-DoD-NASA) program established February 11, 1983, began evaluating approaches to nuclear-reactor space power systems. Nuclear reactors can greatly expand opportunities and performance of future civil and defense missions. (See also the Department of Energy chapter.)

Photovoltaic concepts using concentrators for converting solar energy to electricity may greatly reduce costs from those of present planar photovoltaic approaches. The efficiency of high-concentration-ratio gallium arsenide cells was increased to more than 19 percent—more than a third higher than that possible with previous technology. A concept recently developed by NASA for a large-area, welded-interconnect, silicon solar array was selected for use in DoD's MILSTAR communications satellite program, and other uses of that technology are expected to materialize rapidly.

Future space systems will require power levels far beyond those of present spacecraft, and major extensions of present thermal management concepts will be needed. NASA began a space thermal management project, which has demonstrated on the ground a heat pipe with a tenfold increase in transport capability (to 20,000 watt-meters) and a flight feasibility test on STS 8 of a two-phase heat pipe for high-capacity applications.

Intensive work continued to define effects of the space environment on space power systems. A space test evaluated the power loss and breakdown phenomena of photovoltaic systems as voltage level and area varied. This information will be used to correlate interaction phenomena measured in space and ground tests for eventual design guidelines for high-power space systems in low earth orbit.

In electrochemical energy, work continued on both advanced batteries and fuel cells. The first preliminary



assembly (breadboard) of an energy storage system using fuel cell and water electrolysis was completed and at the end of the year was being tested in simulated low-earth-orbit environment in the laboratory.

#### *Shuttle Flight-Test Results*

Flying research experiments on the Shuttle orbiter has expanded the data base on orbiter performance and characteristics. The high-resolution accelerometer package (HIRAP) was flown on STS flights 6 through 8 to determine the orbiter's lift-to-drag ratio in the free molecular flow regime.

In-space technology experiments continue research begun in the ground-based laboratory when the unique environment of space (micro-gravity, vacuum, and combined radiation) is essential to the development of technology for future space missions.

In 1983, several experiments completed fabrication and began assembly and integration for launch in 1984. The solar-array flight experiment to validate lightweight and high-power solar-array technology will begin payload integration in 1984 for a mid-year Shuttle launch. The tribology experiment already integrated into Spacelab 1 will provide data on zero-gravity effects on hydrodynamic films formed in journal bearings. Verification of technology will be sought with an early 1984 flight of the feature identification and location experiment (FILE).

Experiments for the long-duration exposure facility (LDEF) completed final acceptance tests in preparation for integration into the facility in early 1984. The facility, carrying 50 experiments, is planned for deployment in mid-FY 1984 and will be retrieved and delivered back to earth in a year. Experiment data will define the effects of long-term space exposure on various materials and components.

### **Space Tracking and Data Systems**

NASA's space tracking and data systems provide tracking, command, telemetry, and data-acquisition support for all NASA programs—earth-orbital science and applications missions, planetary missions, expendable launch vehicles, sounding rockets, balloons, research aircraft, and the Space Transportation System. The Deep Space Network (DSN), the Spaceflight Tracking and Data Network (STDN), the Space Network (SN), and various facilities provided this support during 1983. A global communications system links tracking sites, control centers, and data-processing facilities that provide real-time data processing for mission control and orbit and attitude determination, as well as routine processing of telemetry data for space missions.

After many years of planning and preparation, a new concept in space operations, the Tracking and Data Relay Satellite System (TDRSS), was begun in

1983. TDRSS is expected to enhance greatly the data retrieval from low-earth-orbital missions and to increase the benefits from space exploration. With TDRSS, the versatility and operational effectiveness of the Space Shuttle, Spacelab, Space Telescope, NOAA operational Landsat satellites, and others are expected to be markedly increased over that provided by ground tracking stations.

#### *Space Network Operations*

The Space Network is a combination of the Tracking and Data Relay Satellite System and the NASA ground systems providing flight support to low-earth-orbital missions compatible with the TDRSS. The major elements include the *TDRS 1* satellite and the White Sands ground terminal, the Network Control Center (NCC), the Operations Support Computing Facility (OSCF), and the Simulations Operations Center (SOC).

A major change was made in the TDRSS service contract. TDRSS was originally conceived as a shared system providing both commercial satellite communications and government mission support capabilities. In December 1982, the contract was modified to dedicate its support to government space missions. The contractor will remain the owner-operator but relinquished its right to use the commercial segment. NASA will have the dedicated use of all spacecraft provided through the service contract, and spacecraft formerly dedicated to the commercial communications service will be used as spares to extend the system lifetime or enhance system capabilities.

The first TDRS satellite was launched on the STS 6 mission in April 1983 and was deployed into a low orbit because of an anomaly during the second-stage burn of the Air Force-provided inertial upper stage (IUS). In May, NASA began maneuvers using the spacecraft's small thrusters to boost it into geosynchronous orbit. In late June, *TDRS 1* reached geosynchronous altitude and, from August 30 through September 5, successfully supported the STS 8 mission. In November, the TDRSS elements supported the STS 9 Spacelab mission, with the satellite relocated to 41° west longitude.

The schedule for launching TDRS-B and -C is dependent on the availability of qualified IUS stages. Planning schedules at the end of 1983 indicated launches in the fall of 1984 and the first half of 1985.

#### *Ground Network Operations*

The Ground Network consists of the Spaceflight Tracking and Data Network, the Deep Space Network, and ground facilities support for aeronautical research, balloon flights, and sounding rockets. During the year, the Ground Network supported both near-earth-orbiting satellites, including the Space Shuttle operational flights, and deep space probes.

Among the numerous applications and scientific earth-orbiting missions were the Space Shuttle missions (STS 6, 7, 8, and 9), *TDRS 1* launch and deployment, *Nimbus 7*, *Landsat 4*, International Ultraviolet Explorer, International Sun-Earth Explorers, Applications Technology Satellites, Solar Maximum Mission, Infrared Astronomical Satellite, Dynamic Explorer, and the Solar Mesospheric Explorer. Solar system exploration support continued for *Pioneer 10* and *11*, *Pioneer-Venus*, the Viking lander, and *Voyager 1* and *2*, as well as limited support for *Helios* and earlier Pioneer missions.

In May, the 64-meter antenna at Goldstone, California, operating as a planetary radar instrument, detected the recently discovered comet IRAS-Araki-Alcock and made measurements of its physical properties that could not be made by other methods.

After supporting the STS 8 night landing in September, the Buckhorn special-purpose tracking station at Dryden Flight Research Facility, California, was phased out and operations terminated. This station had been established to support the Space Shuttle approach and landing tests and the operational flight test landings.

#### *Control Centers and Data Processing*

NASA's control and data-processing facilities command and control the unmanned scientific and applications satellites: payload operations control centers and related mission support systems receive, process, and display spacecraft telemetry data and transmit commands to the spacecraft. Some 17 spacecraft were monitored and controlled during 1983 by five control centers operated under the Space Tracking and Data Systems Office. A new control center was being developed for dedicated support to the *Space Telescope*. Hardware had been delivered and installed and early releases of software development had been completed by the end of the year. The Spacelab Data Processing Facility was completed and tested in time to process data from the November Spacelab mission.

### **Aeronautical Research and Technology**

The advances in technology derived from NASA's aeronautics program ensure the continued success of the U.S. aeronautics industry, thereby contributing to the development of a superior military capability and to a safe and efficient civil air transportation system. These advances depend on maintaining an expert technical staff to conduct the research as well as on providing superior research facilities, including the latest state-of-the-art simulation and high-performance computational facilities.

During 1983, NASA began operation of a highly sophisticated full-mission and full-system flight simulator—the Man Vehicle Systems Research Facili-

ty at Ames Research Center. Human error is responsible for, or a contributing factor in, 60 to 80 percent of domestic aircraft accidents. This facility will make major contributions to design and use of the cockpits of future generations of aircraft.

Lewis Research Center significantly enhanced its computational capabilities during 1983 with the acquisition of a Cray 1S computer. This new "supercomputer" will permit researchers to predict accurately the internal physics and overall performance of propulsion systems.

The Avionics Integration Research Laboratory (AIRLAB) at Langley Research Center also began operations in 1983. This unique facility addresses the major research problems in the integration of avionics and control systems in future aircraft by providing tools to evaluate and demonstrate the safety, reliability, performance, and economics of fully integrated systems.

Also at Langley, the National Transonic Facility, a cryogenically cooled wind tunnel that can simulate conditions of flight Reynolds numbers (ratio of momentum to viscous forces in fluid flow about a body), began operations in 1983 after shakedown and acceptance tests were completed.

#### *Maintaining a Strong Technology Base*

NASA's disciplinary research seeks to improve the understanding of basic physical phenomena and develop new concepts in fluid and thermal physics, materials and structures, controls and human factors, and computer science and electronics.

*Fluid and Thermal Physics.* During the past year, new computational methods applied to transonic compressor-blade designs permitted increased pressure rise with fewer compressor blades. These methods could result in significant reductions in both experimental development time and cost for advanced engine designs. The turbine hot section is the life-limiting component in aircraft gas-turbine engines, and the largest future gains in engine performance will come through future increases in operating pressures and temperatures. During 1983, Lewis Research Center completed an in-house laboratory for basic combustion research that will enhance our ability to analyze gas turbine combustion and heat transfer processes.

A program to evaluate low-drag laminar flow over wings demonstrated under the laboratory conditions a potential 20-percent reduction of turbulent air friction over aircraft surfaces.

*Materials and Structure.* The NASA program in advanced metallic systems for more efficient airframes made steady progress in the characterization of new powder-aluminum alloys exhibiting higher strength, lower density, and greater temperature capability. Lightweight graphite-polyimide composites reached a new level of acceptance for gas-turbine engines as a

result of a joint NASA-Navy study. Under the program, a graphite-polyimide outer fan duct for the General Electric F-404 turbine engine was successfully manufactured and tested. The new duct replaces a heavier and more expensive one made of titanium.

As part of the research program in aeroelasticity, a "decoupler pylon" for the passive alleviation of flutter induced by the attachment of weapons, fuel tanks, etc., on an F-16 aircraft was developed, fabricated, and ground-tested in preparation for an early 1984 flight by NASA on an aircraft provided by the Air Force.

*Controls and Human Factors.* During 1983, flight-critical systems research was a major element in the controls and guidance program. Engineering models of the fault-tolerant multiprocessor (FTMP) and the software-implemented fault-tolerant (SIFT) computer have been installed for further testing in the newly opened AIRLAB facility at Langley Research Center. CARE III, the computer-aided reliability estimation program, an important analytical tool for assessing the reliability of fault-tolerant systems, has been developed and installed in AIRLAB. CARE III was used at the Grumman Aerospace Company to assess the reliability of the flight control system on the X-29A aircraft. Concern with the effects of lightning on digital electronics has led to increased research in lightning phenomena and developing protection techniques. The research program for flight management continued to develop a basic understanding of information transfer, decision making, and resources management in the cockpit to provide a data base for improved cockpit systems and operational procedures.

*Computer Science and Electronics.* Completing its first year of activity, the new computer science and applications program developed a technical foundation within NASA to exploit advancing computing technology in aerospace applications. Focusing on concurrent processing, reliable computing, software engineering, and information management, the program awarded a block grant to the Massachusetts Institute of Technology to develop a center of excellence in aerospace computing, opened the Research Institute for Advanced Computer Science (RIACS) at Ames Research Center, and began research and development programs at Ames and Langley Research Centers to develop core skills within NASA. Equally important is the development of pioneering applications of the computer to aerospace problems.

#### *Systems Research for Future Applications*

Systems research and technology programs focus on the technology needs of future aircraft, integrating the various aeronautical disciplines to provide an understanding of interactions among system components. Work during 1983 was directed at improved performance and fuel efficiency, short- and vertical-

takeoff and landing capability, and supersonic cruise technology.

*Powered Lift.* Models of two promising single-engine supersonic short-takeoff and vertical-landing fighter attack aircraft were designed and fabricated. One uses an ejector augmentor; the other is based on plenum burning. The ejector model began wind-tunnel testing in 1983, and the plenum-burning model will be tested in the spring of 1984. A free-flight model of the ejector concept, for flight controls evaluation, is scheduled for wind-tunnel testing in the fall of 1984. A 0.3-scale model of the ejector configuration will be tested for ejector performance and ground effects in the wind tunnel in late 1984.

Testing aircraft models with a realistic representation of a propulsion system is expected to provide more valid predictions of full-scale aircraft characteristics. New propulsion simulators were checked out and installed in a twin-engine fighter model. Wind-tunnel testing will be conducted to compare data previously obtained on the same fighter model equipped with single flow-through nacelles to data obtained with a nacelle with simulated jet-exhaust effects but no inlet airflow.

*Supersonic Cruise Technology.* The technology for supersonic military aircraft focused on integration of "two-dimensional" nozzles, with both thrust vectoring and thrust reversing. Studies of advanced aircraft incorporating these features indicate they can operate from short field lengths (less than 300 meters) with a radius of action of more than 900 kilometers at mach 2.0 cruise, at the same size and weight as today's fighter aircraft.

Analytical research in supersonic inlets included the development of three-dimensional viscous analysis codes that can analyze axisymmetric nozzles at angles of attack and yaw. After experimental verification, it will be possible to design three-dimensional conformal inlets for improved integration of propulsion and airframe to meet both design and off-design conditions.

*Energy-Efficient Engines.* In research to increase efficiency of engines, an advanced engine core was combined with low-spool components in an integrated research test vehicle. An engine that was operated over the complete range of conditions possible at sea level, including the full takeoff power rating, gave good integrated-component performance and showed excellent engine starting and transient capabilities. The test vehicle's full-scale mixer exhibited about eight percent better mixing than obtained in scale model tests, with the attendant improvement in thrust and efficiency. New logic for full-authority digital engine control permitted normal engine operation with as many as three control sensors intentionally failed. The integrated core and low spool, composed of research components, used 13.2 percent less fuel than did the engine representing existing technology. With full development of these components, an advanced-

turbofan production engine is expected to use more than 15 percent less fuel than existing engines.

**Propulsion.** A technological barrier was overcome in high-temperature electronic instrumentation. Silicon carbide offered the properties needed for electronic instrumentation capability above 500°C for use in hot sections of gas turbines, but no repeatable manufacturing process was available. During 1983, a practical, repeatable, chemical-vapor-deposition process was developed that produced crystals of excellent quality. Work began on diodes using the silicon carbide crystals. In addition to the instrumentation applications, the new manufacturing technology will benefit a variety of future development projects requiring high-temperature electronic components.

Stall recovery tests on a representative high-bypass engine produced repeatable nonrecoverable stalls. The tests provided valuable data for verifying engine simulations recently developed to predict nonrecoverable stalls in future turbofan engines. Future investigations of nonrecoverable stall phenomena will build on these data.

**Advanced Turboprop Program.** The preliminary design of a large-scale (2.7- to 3-meter-diameter) propeller was approved, and the propeller will be fabricated and ground-tested in preparation for potential airframe integration and possible flight research. Experimental programs in acoustics include both cabin-environment and far-field noise measurements. Acoustic test data showed that structure-borne noise was produced primarily by propeller-wake effects on the wing. In-flight measurement of propeller far-field noise characteristics indicated that single-rotation propeller noise would be well within noise levels of Federal Aviation Regulation 36, stage 3, and lower than comparable turbofan-powered aircraft levels.

**Helicopter Technology.** NASA and four major U.S. helicopter companies represented by the American Helicopter Society launched a program in 1983 to reduce helicopter noise. The program will coordinate NASA contracts and in-house and company research, as well as FAA and Army research, to avoid duplication and to share results. A data base on two-bladed rotors (AH-1J helicopter) was completed, using flight and wind-tunnel testing, and hardware was being procured to assemble a more extensive data base on a modern, four-bladed rotor (UH-60 helicopter). Small-scale wind-tunnel testing began on the rotor to investigate aerodynamic and acoustical interaction among the main rotor, tail rotor, and fuselage.

Initial flight tests of a rotor-blade de-icing boot were completed; however, further work remains to make the concept efficient. Studies of the feasibility of significantly augmenting engine power by injecting water into the cooling air film for turbines were completed and a program to develop hardware was begun.

**Transport Aircraft Laminar Flow.** Laminar flow control is a technology with great potential for drag reduction

and, hence, fuel savings. Laminar boundary layers can be stabilized by either favorable pressure gradients (natural laminar flow) or small amounts of wall suction (laminar flow control). NASA's program for development of a laminar-flow technology base for application to commercial transports has made significant progress toward exploiting new materials, fabrication methods, analysis techniques, and design concepts and is providing convincing evidence that practical control systems could become a reality. The most difficult problems in achieving laminar flow appear to be associated with the leading-edge region of the wing, which is subjected to foreign object damage, insect impingement, rain erosion, icing, and other contaminants. Present efforts focus on developing a practical, durable leading-edge structure that contains a suction system, cleaning system, and an anti-icing system. Two fully functional leading-edge test articles were designed, fabricated, and installed on a JetStar aircraft. Systems evaluation and performance testing began in November 1983.

#### *Technical Support for the Military*

A primary goal of the NASA aeronautics program is the continued superiority of U.S. military aviation, and to that end NASA conducts a number of programs in cooperation with the Department of Defense. These include both high-performance aircraft and rotorcraft.

**Advanced Fighter Technology Integration (AFTI).** The joint Air Force-NASA AFTI effort consists of two technology programs directed at future fighter applications. The AFTI/F-16 incorporates an advanced digital fly-by-wire control system and canard surfaces for direct force control. Flight tests of the digital flight-control system (DFCS) were completed in late July 1983. At the end of 1983, the vehicle was being modified to test the automatic maneuvering-attack system (AMAS), scheduled to begin in the spring of 1984.

The AFTI/F-111 mission-adaptive wing (MAW) will demonstrate improvements in aerodynamic performance provided by a smooth, variable-camber airfoil. The supercritical wing, using smooth leading- and trailing-edge devices, can assume many shapes for optimum performance over a wide operating envelope. During 1983, Boeing Aerospace Company delivered the wings to Dryden Flight Research Facility for installation and checkout on the F-111 aircraft. Flight research was scheduled to begin in the summer of 1984.

**X-29 Forward-Swept-Wing Flight Demonstrator.** NASA supports development of the X-29A forward-swept-wing flight demonstrator funded by the Defense Advanced Research Projects Agency (DARPA). Wind-tunnel tests at Ames and Langley Research Centers obtained aerodynamic and structural data on the airframe, and piloted simulation tests were conducted at



the Dryden facility. Technical support was also provided for instrumentation, structural dynamics, handling qualities, and control systems. First flights were scheduled for mid-1984.

*RSRA/X-Wing Flight Demonstration.* NASA also supports a DARPA-led program to fly the stopped-rotor X-wing concept on the rotor systems research aircraft (RSRA). In 1983, NASA delivered one RSRA to the contractor for modification and ferried the other to Dryden to begin tests as a fixed-wing aircraft (without the S-61 rotor). Technical support also included two-dimensional airfoil testing and the first testing of a unique, convertible fan/shaft engine.

*Tilt Rotor/JVX Aircraft Support.* NASA continues to augment the technology base for the proposed DoD joint vertical-lift aircraft (JVX). Flight testing on the NASA-Army XV-15 aircraft included short takeoff and landing performance, maneuvers, wake surveys, control system evaluations, and operational suitability demonstrations such as external lift and air-to-air refueling. Ground-based testing centered on small-scale wing-rotor download investigations as well as research using the vertical motion simulator and preparations for full-scale testing in 1984 and 1985. Fabrication of advanced rotor blades was completed for a series of tests that also included XV-15 and preliminary JVX blades.

#### *Improving Aircraft Safety and Efficiency*

Providing a safe and efficient transportation system for the nation's growing number of air travelers is a continuing challenge. NASA helps meet that challenge through research activities coordinated closely with the Federal Aviation Administration.

*Aviation Safety.* Progress continued in 1983 in defining atmospheric hazards and advancing technology for fire and crash safety. Major advances in the characterization of atmospheric lightning continued, with the accumulation of 226 direct lightning strikes on the Langley F-106B research aircraft bringing the four-year program total to 402. DoD and NASA are using this data to design new lightning protection for advanced aircraft systems.

NASA participated in an extensive study by the National Research Council on wind-shear hazards to

aviation. Wind-shear data collected in the interagency program making Doppler radar measurements in Denver during 1982 have been used in research at Langley. Ames is also using this data in a jet transport simulator to assist FAA and airlines in pilot training to cope with this recurring hazard.

Flight research continued in atmospheric icing conditions, using the Lewis Twin Otter to gather data and compare inflight performance of instrumentation and advanced anti-icing and de-icing concepts with the results of tests in the Lewis Icing Research Tunnel. Langley, in cooperation with FAA, began research on aircraft stopping performance on wet and snow-covered runways, using various ground vehicles to measure loss of braking traction. The Langley B-737 transport systems research vehicle and four ground vehicles collected high-quality friction data under these nonstandard conditions during 450 test runs on controlled runway surfaces at the Wallops Flight Facility and FAA Technical Center. The data will be used for aircrew training and operational decisions in degraded weather conditions.

In cooperation with the FAA, NASA continued development of advanced, lightweight, fireworthy materials to reduce the threat of fire in aircraft cabins. The new Ames fire-blocking layered seat cushions, in FAA tests under full-scale postcrash fire conditions, increased occupant escape time by one minute. Ames began development of interior wall panels for aircraft cabins that show promise of further increasing occupant survival times. NASA-FAA safety research continued preparation for a remotely controlled crash of a civil jet transport, scheduled for 1984 at Dryden Flight Research Facility. This demonstration will include use of antimisting-kerosene safety fuel, measurement of structural loads, and evaluation of the crashworthiness of metallic and composite structures.

*Advanced Transport Operating System.* A research facility has been developed to test crew systems in a full mission environment. High-fidelity simulation of mid-1990s generic transports examines cockpit and crew integration concepts that will permit efficient transfer of information between the flight crew, on-board systems, and air traffic control; improve situation awareness; and improve the pilot's ability to function effectively.

# Department of Defense

The Department of Defense (DoD) pursues advances in space communications, navigation, meteorology, surveillance, and aeronautics to maintain the security of the United States. Cooperation with NASA and other federal agencies also produces civil benefits. In 1983, a presidential directive provided another new focus for the DoD space systems. This focus, the Strategic Defense Initiative, is an effort to define a long-term research and development program to explore strategic defense technology for the ultimate goal of eliminating the threat posed by ballistic missiles.

Also in 1983, the Navstar Global Positioning System entered the production phase with the award of a multiyear contract for 28 GPS satellites. The first Shuttle inertial upper stage was launched in April 1983 to place the first Tracking and Data Relay Satellite (*TDRS 1*) in orbit. And ground-breaking ceremonies marked the start of construction of the Consolidated Space Operations Center near Colorado Springs.

In keeping with this increased emphasis on space, the Navy consolidated its space activities, establishing the Naval Space Command at Dahlgren, Virginia. This command will be the functional equivalent of the recently established USAF Space Command.

## Space Activities

### *Military Satellite Communications*

**MILSATCOM.** Satellite communications systems provide a unique solution to many communications problems and are therefore an indispensable element of our force structure in peacetime, in crises, and in war. Because these systems play a vital role in our worldwide commitments, it is imperative that they be both reliable and able to survive and sustain operations at any level of conflict. These considerations led DoD to develop a Military Satellite Communications (MILSATCOM) system responsive to a wide range of requirements and threats. MILSATCOM ensures support to three main user communities: (1) command and support forces of the commanders-in-chief and military services and agencies; (2) strategic and tactical nuclear forces; and (3) strategic and tactical conventional forces.

In 1983, support continued to be provided primarily by a range of first-generation MILSATCOM systems and lease of selected commercial SATCOM circuits. Approaches for enhancing the survivability of SATCOM to augment DoD systems during periods of national emergency are being studied under the guidance of the National Security Telecommunications Advisory Committee (NSTAC).

**Defense Satellite Communications System (DSCS).** The command and support forces continued to be served primarily by the Defense Satellite Communications System (DSCS). The space segment in 1983 was composed mostly of DSCS Phase II spacecraft. The first DSCS III satellite, launched in late 1982, was declared fully operational in May 1983, with significantly improved physical and electronic survivability for the high-data-rate communications of DoD, Department of State, and allied nations. Additional DSCS III satellites are in production for launch as required. DSCS operates at superhigh frequency (SHF) in supporting a large population of fixed and mobile terminals worldwide.

The DSCS program continued to retire obsolete ground terminals, and nearly all of 21 previously approved AN/GSC-39 terminals were delivered. The first of 39 medium terminals reflecting the latest technology will not be delivered until early 1985. A contract for the satellite-configuration-control element (SCCE) was awarded in September 1983. The SCCE is a major component of the DSCS operational system for automated control of DSCS satellites and allocation of their resources among users. The Navy's SHF SATCOM terminal AN/WSC-6, with the OM-55 modem, will be installed aboard fleet flag ships to provide jam-resistant communications for commanders of numbered fleets. The AN/SWC-6 will also be installed aboard 12 surface-towed-array surveillance system (SURTASS) ships with the MD-1030A modem. First flagship installation is scheduled for early fiscal 1985 with SURTASS installation to begin March 1984.

The DSCS system is also converting from analog communications to totally digital transmission by the late 1980s. Nearly three-quarters of the DSCS sites at the end of 1983 had a digital communications subsystem. The first of eight operation centers in the DSCS operations control system became operational at

Sunnyvale, California, in May. All eight centers will be operational by 1987.

*Air Force Satellite Communications System (AFSATCOM).* The strategic and tactical nuclear-capable forces are also served by the Air Force Satellite Communications System. AFSATCOM consists of packages on the Satellite Data System (SDS), the Fleet Satellite Communications System (FLTSATCOM), and other host satellites. Full operational capability for the AFSATCOM system was achieved in December 1983.

*Fleet Satellite Communications System (FLTSATCOM).* The Navy-managed four-satellite Fleet Satellite Communications System continued to provide almost worldwide low- or moderate-data-rate service to strategic and tactical conventional forces. More than 17 spacecraft years of service have been provided to the Navy, to commanders-in-chief of the Unified and Specified Commands, and to other high-priority users.

Ultrahigh-frequency (UHF) SATCOM is the primary military communication link for strategic and tactical mobile forces of the Unified and Specified Commands. Navy's UHF SATCOM system, provided by FLTSAT and GAPFILLER space segments, form the backbone of day-to-day communications and crisis management capability for forces afloat. GAPFILLER is the leased segment of three commercial Marisat satellites positioned for optimum ocean coverage. Present FLTSAT satellites, launched February 1978 through October 1980, are expected to provide service into 1985-1987. GAPFILLER satellites launched in 1976-1977 are expected to provide service well into 1985.

The need for DoD UHF SATCOM capability will continue at least into the 21st century. To continue these services, launching of four Leased Satellites (LEASATs) by Space Shuttle will begin in June 1984. The long-established FLTSAT system will be extended with the launch of three satellites, beginning in late 1985 with *FLTSAT 6*. *FLTSAT 7* and *8* will incorporate an extremely-high-frequency (EHF) package for a limited MILSTAR capability and EHF terminal development.

*Army Satellite Communications Activities.* The Army funds development of satellite communication ground terminals for use by all the armed services and other government agencies. This program provides rapid, reliable, effective communications to support command and control requirements for tactical and strategic commanders, as well as the National Command Authority and the Defense Communications System.

Use of satellite communications by ground formations continued to increase. Delivery of AN/TSC-85A and AN/TSC-93A tactical satellite terminals will begin in July 1984. The terminals operate in the SHF band, which greatly enhances traffic handling and resistance to enemy jamming. First article test for the UHF man-

pack and vehicular-mounted satellite terminals AN/PSC-3 and VSC-7 began in July 1983. Distribution of these units to the field in support of special operations forces will begin in 1984.

*New Satellite Communications Initiatives.* Concept validation studies for the EHF MILSTAR satellite communications system were concluded. The Air Force Joint Milstar Program Office (JMPO) awarded a contract to Lockheed Missiles and Space Company for full-scale development of the satellite and a control capability able to survive in conflict. Development of a scaled-down, MILSTAR-compatible package by MIT Lincoln Laboratory for FLTSATCOM satellites, to support operational testing of terminals, continued.

The Navy was designated to head the Joint Terminal Program Office (JTPO), which is overseeing MILSTAR terminal development by each of the services to maximize commonality, interoperability, and logistic supportability. The Navy began its full-scale development program in 1982, to develop terminals for shipboard use. The Air Force awarded the first phase of a two-phase contract in September 1983, using a leader-follower procurement approach designed to promote competition during production. The Air Force program will develop terminals for all airborne applications. The Army planned to award a low-rate initial production contract in January 1984 for its single-channel-objective tactical terminal (SCOTT). SCOTT will operate in the EHF band, which enhances its resistance to enemy jamming. Some 100 terminals will be procured to support early needs of the National Command Authority, Joint Chiefs of Staff, and Army.

All these terminals will be tested using the Lincoln Laboratory-developed MILSTAR-compatible EHF package to be launched on *FLTSATCOM 7* and *8* satellites. The package will also permit early verification of MILSTAR spacecraft technology and operational concepts.

Army development of a multichannel terminal in the EHF band, for high-traffic-volume users, continued, as well as exploratory analysis for lighter, advanced, manpack terminals operating in EHF.

Development of technology continued for communication from space through clouds and water to submarines at operational depths without comprising their security or limiting their flexibility, in the Defense Advanced Research Project Agency (DARPA) and Navy's Submarine Laser Communications (SLC) program. Early tactical SLC capabilities are expected from an airborne system to cover limited areas. A space-based SLC system could provide global coverage, survivability, and flexibility in both tactical and strategic operations, but presents formidable technical challenges.

Program strategy is to test, by 1984-1985, under realistic conditions, the technology supporting airborne tactical SLC and to assign that part of the pro-

gram to the Navy for engineering development and exploitation. In the far term, the program is to support an informed decision on whether to deploy an SLC satellite system. In 1983, two receivers for tactical airborne applications were delivered to the government for laboratory testing, with the transmitter in final fabrication. Atmospheric-compensation field experiments test transmission of beams to a high-altitude aircraft, and technology for a deformable mirror was demonstrated.

Studies were begun to reexamine requirements of the Command Support Forces through the 1990s and to plan improvements in the DSCS system if they are required. Additional studies were begun to define methods of providing follow-on UHF service after the end of the FLTSAT and LEASAT systems in the early 1990s.

*Advanced Space Communications Technology.* DoD's Advanced Space Communications program develops technology, techniques, and concepts for improving present and future military satellite communications systems. A contract was awarded to provide a MILSTAR-compatible modem for the AN/ASC-30 airborne command post terminal for early testing of EHF communications. Solid-state and traveling-wave-tube amplifier development continued, for reliable, long-life transmitters for future satellite downlinks. Efforts to develop radiation-resistant signal-processing technology for use on future satellites began. A cooperative NASA and Air Force program in satellite-to-satellite crosslink technology development also began in 1983.

#### *Navigation and Geodesy*

The TRANSIT navigation-satellite constellation consists of five satellites that have been used by Navy strategic-ballistic-missile submarines and numerous military and civil users for the past 18 years. Production of three improved TRANSIT satellites called NOVA was completed in 1983 with delivery of *NOVA 2* and *NOVA 3* in October. *NOVA 1* has been operational since July 1981. The NOVA satellite have improved orbit determination and stationkeeping, extending the time between updatings from ground stations.

In 1983, the Navstar Global Positioning System (GPS) entered the production phase with the May award of a multiyear contract for 28 GPS satellites. Deliveries starting in fiscal 1986 will lead to a full operational capability by the end of 1988. Two contractors, Rockwell/Collins and Magnavox, are continuing their development of a family of GPS user equipment for participating services and agencies. Equipment has been delivered to the government for testing on eight multiservice platforms including fighters, tanks, bombers, an aircraft carrier, and a submarine. The M-35 truck continued field tests. A May 1983 "pre-run" of the manpack developmental test and

evaluation gave excellent results, partially exceeding specification values. Some missions were conducted in rugged terrain in order to mask satellites for longer periods. Installation in the UH-1D helicopter and M-60 tank was completed in preparation for operational test and evaluation in 1984. A production decision is expected early in 1985.

Work on the Defense Mapping Agency's GPS geodetic receivers continued, with successful operation of these systems also indicated. These units, which will provide information on precise geodetic positions worldwide in support of DoD missions, will be phased into operation during 1984.

The Navy geodetic and geophysical satellite, *GEOSAT*, is scheduled to be launched in September 1984 to measure the ocean's surface accurately for a precise marine geoid. This precision is necessary to support the increased accuracy requirements of the Trident II (D-5) missile. The *GEOSAT* program was begun in 1982, and the geodesy portion of the satellite's mission will be completed in 18 months. Engineering modifications are being considered to extend the life of the altimeter sensor for an additional oceanographic mission of 18 months, to measure wave heights and surface winds and to locate ocean fronts and eddies. At the end of 1983, the spacecraft had been assembled and was undergoing flight-qualification tests before integration with the refurbished Atlas E launch vehicle.

#### *Meteorology and Oceanography*

The first block 5D-2 DMSP satellite was launched in December 1982, followed by the second 5D-2 satellite in November 1983, in the Defense Meteorological Satellite Program to provide high-resolution visible and infrared imagery of clouds, atmospheric soundings of moisture content and temperature, and ionospheric monitoring for DoD strategic and tactical weather requirements. Data support Air Force, Navy, and Marine Corps mobile readout stations or Navy carrier task forces. Each DMSP satellite provides full earth coverage twice a day. In 1983, Congress approved and the Air Force began multiyear procurement of four block 5D-2 spacecraft and imaging sensors. These satellites will provide DMSP coverage until transition to the Space Shuttle.

Meteorological information stored on DMSP satellites is played back over the United States and processed by the Air Force Global Weather Center and the Navy Fleet Numerical Oceanography Center before being merged with Department of Commerce satellite information. Environmental data and forecasts are transmitted through a worldwide network of weather stations to Army, Navy, and Air Force operating units. Tactical aviation forecasts and general and severe weather forecasts—in addition to tailored forecasts for specific weapons, sensors, and platforms—are routinely available 24 hours each day for all areas of the globe.



The Air Force and Marine Corps are procuring a new generation of deployable tactical vans that can be transported in C-130 aircraft. The first units have been operationally deployed. The vans, established tactical ground stations, and Navy forces at sea receive data directly from each satellite as it passes over their vicinity. This local-area readout is used by the deployed forces for immediate decision assistance.

The Navy Remote Ocean-Sensing System (*N-ROSS*)—a Navy oceanographic satellite capitalizing on technology developed and demonstrated by NASA's *Seasat* in 1978—is planned for launch in the late 1980s. The Navy manages the project with cooperation and contributions from NASA (sensor), National Oceanic and Atmospheric Administration (space bus and integration money), and Air Force (launch vehicle and command and control services). *N-ROSS* will transmit data describing the state of the surface of the world's oceans, improving the accuracy of the atmospheric and oceanographic tactical information required by U.S. military forces. Although begun to meet the needs of DoD, the data will also be made available to the civil government and scientific communities.

#### *Surveillance and Warning*

Early-warning satellites provide early-warning data on missiles to the National Command Authorities, Strategic Air Command, and the North American Air Defense Command. DoD is developing a nearly instantaneous, fully responsive space-based space-surveillance system that can survive attack and will monitor threats from space-based systems in the 1990s. The DoD system is the key element of a comprehensive space-surveillance plan completed last year for evolutionary development of advanced systems to meet needs through the year 2000. It also has application to surveillance for defense against ballistic missiles.

DARPA continued to support advanced surveillance technology for infrared and radar sensors deployable on surface, airborne, and space-based platforms. Projects are to develop and demonstrate critical elements of electrooptical sensor technology, space-based radar concepts, and space signal processing. The DARPA Teal Ruby program—a space-based experiment begun in 1977 to evaluate infrared surveillance and prove concepts for other multimission surveillance functions—completed the major portion of its qualification test program in 1983, including acoustical and radiometric testing. Responsivity noise and uniformity levels for the focal plane were being determined at the end of the year. The Teal Ruby flight-sensor components were being tested in preparation for sensor assembly. Also during 1983, the DARPA Infrared Surveillance Technology Base Program was developing critical components for future capabilities in detecting hostile missions and aircraft and satellite targets. A breadboard model of an advanced onboard signal processor (AOSP) was demonstrated. This program is

developing a multiapplication signal processor using advanced design and high-speed and low-power microelectronic technology, for support of all projected military space missions to the year 2000. A larger breadboard AOSP is planned to demonstrate a specific, large-scale, infrared signal-processing application.

The multiyear modernization program to improve accuracy and sensitivity of the U.S. Naval Space Surveillance System (NAVSPASUR) continued during 1983. As part of the North American Aerospace Defense System's Detection and Tracking System (SPADATS), NAVSPASUR tracks satellites and other space objects and maintains a catalog of them at Dahlgren, Virginia.

*Space-Based Laser.* The Space Laser Triad program, the three-project DARPA portion of the joint Air Force-DARPA Space-Based Laser effort, continued to work toward demonstration of the key technology required for a space-based laser weapon system.

*Antisatellite System.* A U.S. antisatellite (ASAT) system is being developed to deter and counter hostile satellite threats to U.S. land, sea, and air forces. The main components are a miniature vehicle interceptor and a two-stage missile consisting of SRAM and ALTAIR boosters. The missile—to be launched from air-defense F-15 aircraft—began captive-carry flight tests in December 1982 and continued during 1983.

*Ballistic Missile Defense.* In 1983, following the presidential direction announcing a goal of eliminating the threat posed by ballistic missiles, a long-term research and development program was prepared to develop the technology required for a highly effective ballistic-missile defense. This program is a departure from previous ones, which emphasized point-defense systems that would protect selected military targets by intercepting reentry vehicles in the terminal phase of their flight with nuclear-tipped interceptors. The new program is designed to lead to a system that could engage ballistic missiles and warheads throughout the launch-to-impact sequence, providing a multilayered defense to protect military and civilian resources in the United States and allied countries. The new defense system would rely on nonnuclear mechanisms (possibly including directed-energy weapons) to destroy an enemy's missiles and reentry vehicles.

The program focuses on technology associated with system concepts and battle management; surveillance, tracking, and discrimination; directed-energy and conventional weapons as possible destruction mechanisms; system survivability and lethality; and command, control, and communications.

*Space Nuclear Power.* The joint NASA-DARPA Technology for Advanced Space Power (TASP) program was begun in 1982 to complement the Department of Energy (DOE) technology development for space nuclear power. The program includes research for a space nuclear-power system, appropriate for military and civil applications, and for a system that

may eventually be necessary to support directed-energy weapons in space.

During 1983, competitive concept definition was begun. A shielding technology program began, and a high-power heat pipe and fuel were tested in concert with DOE. A safety plan is being completed. The TASP program is exploring alternate concepts and technology for a 1985-1986 decision on whether to begin engineering development.

#### *Space Transportation*

*Expendable Launch Vehicles.* During 1983, DoD launched 11 missions on expendable launch vehicles, using Titan III and Atlas E vehicles, in addition to 1 launched by NASA for DoD on a Scout. In June 1983, the Air Force began termination of production of Titan III vehicles. DoD also began to assist in carrying out the President's May policy statement on commercialization of expendable launch vehicles (see appendix F). The department began identifying information and facilities available to commercial users and pricing services required by the users.

*Space Shuttle.* The National Aeronautics and Space Administration and DoD are partners in developing and operating the Space Shuttle. NASA has the development and operation responsibilities for the Space Shuttle vehicle; the East Coast Shuttle launch and landing facilities at Kennedy Space Center, Florida; and the Mission Control Center at Johnson Space Center, Texas. The Air Force responsibilities include development of the inertial upper stage (IUS) and development and operation of the West Coast Shuttle launch and landing facilities at Vandenberg Air Force Base, California, for both defense and civil missions. The Air Force is also funding modifications of existing NASA facilities and equipment to accommodate classified operations at Johnson, Kennedy, and Goddard Space Centers. Construction of the major facilities at Vandenberg is essentially complete, and installation of support equipment is well under way. Planning began on DoD payloads for a first flight in October 1985. Vandenberg will provide a Shuttle capability to launch satellites into polar orbit, which cannot be reached from the eastern launch site at Kennedy.

*Upper Stage Programs.* Space Shuttle upper stages include the commercial PAM-D and PAM-A (which can carry 450 to 1,400 kilograms to geosynchronous orbit), the Air Force IUS (2,300 kg to geosynchronous orbit), and the joint NASA-Air Force Centaur (4,500 kg to geosynchronous orbit). In October 1983, the Air Force awarded a multiyear contract for 28 PAM-D vehicles to support the Navstar Global Positioning System.

Following the first launch of the IUS on a Titan III in October 1982, successfully placing a DSCS II satellite in orbit, the first Shuttle IUS launched the Tracking and Data Relay Satellite *TDRS 1* in 1983. Because of a malfunction of the IUS, the satellite was

placed in an elliptical orbit. Subsequently orbit adjustments by the TDRS propulsion system moved the satellite into its proper orbit. An anomaly investigation team determined the problem to be in the gimbal mechanism of the second-stage motor. A recovery plan to correct the motor was established, and IUS flights are expected to resume in late 1984.

The joint Centaur program will develop two configurations. The first is the Centaur G (6 meters long with 4,500-kg-to-geosynchronous capability), which will be the basic configuration for common use by NASA and DoD. The second configuration will be a stretched Centaur G, with increased performance for the 1986 *Galileo* and International Solar Polar (*ISPM*) missions.

*Space Station.* During 1983, DoD evaluated a number of contractor and Air Force studies of the potential military utility of a national manned space station and the appropriate level of USAF and DoD participation and investment. DoD determined that it would take the role of a user of the station for research, development, test, and evaluation and would continue to participate with NASA during NASA's planned three-year definition of requirements.

*Space Vehicle Subsystem R&D.* The Air Force continued development of advanced spacecraft technology in space navigation, power, and computers and electronics. Autonomous-navigation, star-sensor-based hardware for increased survivability was built for laboratory testing. Hardened computer and electronics components were also built for fiscal 1984 testing. Advanced space technology planning was conducted through continued development of the Military Space Systems Technology Model (MSSTM). MSSTM provides Air Force technology planners a broad overview of potential military space missions and defines technology development areas for projected future mission capability. Of particular importance is identification of the critical need for hardened electronics. The Air Force Space Test Program's Spacecraft Charging at High Altitude (*SCATHA*) spacecraft, launched into geosynchronous orbit in 1979, continues to provide extensive data on spacecraft electrical-charging phenomena.

*Space Test Program.* The Space Test Program (STP) launched two space missions during 1983. The first, consisting of a Naval Research Lab EUV spectrometer and other instrumentation, was launched on June 18 aboard STS 7 in a get-away-special container. This experiment obtained earth-background-radiation data and used the first flight container with an opening lid—a joint NASA-STP development. The second, consisting of Defense Nuclear Agency and Air Force Geophysics Laboratory experiments to study the effects of ionospheric plasmas on radio propagation, was launched on a Scout launch vehicle from Vandenberg AFB on June 27. The mission experiments were integrated on a surplus Navy TRANSIT satellite. The

Scout launch vehicle was obtained from NASA (it was surplus to NASA program needs).

NASA and the Air Force Space Test Program are developing the Combined Release and Radiation Effects Satellite (*CRRES*). This joint program will develop and fly from the Shuttle a free-flying spacecraft that will perform a NASA chemical-release mission during three months in a low earth orbit and then will boost itself into a high-altitude, elliptic orbit for a DoD mission to evaluate the performance of advanced microelectronic components in a high-radiation space environment. The Air Force will fund the *CRRES* spacecraft, and NASA will fund the Shuttle integration and launch of the spacecraft. Data from both of the *CRRES* missions will support development of future DoD and NASA spacecraft.

In another joint effort, the Space Test Program will fly five DoD experiments on the first NASA Long-Duration Exposure Facility (*LDEF*) mission. The *LDEF* was scheduled to be deployed from STS 13 in April 1984 and retrieved about May 1985 by a to-be-determined STS mission.

## Aeronautical Activities

### *Fixed-Wing Program*

**Bomber Development.** The B-1B multirole bomber, produced by Rockwell International, is a derivative of a proved product, the B-1A, with about 80 percent of the two designs in common. Production of the B-1B began in January 1982, with a plan to acquire 100 B-1Bs for an estimated cost of \$20.5 billion (in constant 1981 dollars). The first production B-1B is scheduled to roll out in October 1984, with its first flight in December 1984 and full operational capability in June 1988.

On March 23, 1983, B-1A number 2, a fully instrumented prototype, began test and evaluation for stability and control, vibration and acoustics, dynamic response, propulsion, flutter, and weapon carriage and separation tests. Analysis will continue until July 1984, when B-1A number 4, which was deployed to the Farnborough Air Show in September 1982, will begin its portion of the B-1B flight test. This B-1A prototype will be modified with the complete B-1B offensive and defensive system groups and will begin heavyweight buildup, offensive and defensive avionics integration, and terrain-following evaluation.

To date, the B-1 program has flown more than 2,000 flight-test hours. The major fuselage components of the first B-1B have been shipped to Palmdale, California, for assembly, and the program remains ahead of schedule and within budget. The program during 1983 emphasized design of hardware and software as well as the redesign of the forward-looking and terrain-following radar systems. The Air Force budget request for the B-1B program in fiscal 1984 will support con-

tinuation of full-scale development activities, engineering fabrication, and assembly of the first B-1B flight-test aircraft.

**F/A-18.** The Secretary of Defense in March 1983 approved full production of the F/A-18 Hornet naval strike fighter—a twin engine, mid-wing, multimission tactical aircraft. Final trials had been completed in 1982. The F/A-18 will replace the Navy's F-4 fighter and A-7 light attack aircraft. The program emphasizes use of proved technology and places highest priority on reliability, maintainability, survivability, and operational versatility. At the end of 1983, three Marine squadrons and two Navy strike fighter squadrons had completed transition into the F/A-18, and preparations had begun for first Navy deployment on the U.S.S. *Constellation*.

**Advanced Tactical Fighter Technologies (ATFT).** The ATFT program will develop technology and concepts and refine required characteristics for the USAF's next-generation tactical fighter aircraft. The Air Force began two ATFT projects in 1983 in accordance with congressional direction: the joint advanced-fighter-engine project, which begins development of new engine design concepts and related technology; and the ATFT airframe concept-development-investigation project, which begins the conceptual studies for an ATFT design. During September 1983, engine contracts were awarded to Pratt & Whitney Aircraft Group and General Electric Company to begin engine design and long-lead critical component hardware. Conceptual airframe contracts were awarded to seven major airframe manufacturers—Boeing Aerospace Corp., General Dynamics Corp., Grumman Aircraft Company, Lockheed California Company, McDonnell Douglas Aircraft Company, Northrop Corp., and Rockwell International—to begin ATF technology and concept development studies. The ATFT program is expected to achieve full-scale engineering development during the late 1980s and produce an advanced tactical fighter with an initial operational capability during the mid-1990s.

**C-5A.** The RDT&E program to develop and test a modified wing for the C-5A aircraft, begun in 1976, was completed in late 1983. The program included 105,000 cyclic test hours of full-scale wing components without any major failures.

The wing-modification production program for the C-5A fleet proceeded on schedule in 1983, with modifications completed on 13 aircraft. Modification of the entire fleet of 77 aircraft is scheduled for completion by July 1987. The wing modification permits the C-5A to attain full mission capability and extends aircraft service life to 30,000 flight hours. A new production program for the C-5B will use a wing of the same basic design. The projected service life of both the C-5A and C-5B is 30,000 flight hours for their design mission use for intertheater airlift for all kinds of

military cargo. They are expected to be operable for this mission well into the next century.

The fixed-price contract for production of 50 new C-5B aircraft was awarded in early 1983. The program is on schedule, with the first aircraft to be delivered in December 1985. Management responsibility for the C-5A wing-modification RDT&E program and the C-5B production program is under the Air Force Systems Command. The C-5A wing-modification production program is managed by the Air Force Logistic Command.

*C-17.* The C-17 transport aircraft is designed to meet U.S. airlift needs efficiently into the 21st century. It will provide the final increment of intertheater airlift capability needed to reach the minimum specified by the congressionally mandated Mobility Study. The 1983 and 1984 development was increased with the addition of \$60 million to complete necessary actions for beginning full-scale development in fiscal 1985. Work continued on wind-tunnel testing, full-scale mockups, reliability and maintainability technology, systems integration, logistics support analysis, and general design analysis and evaluation. All analyses thus far have met or exceeded C-17 design specifications.

*T-46A (Next-Generation Trainer).* The T-46A will replace the aging, operationally deficient T-37 primary trainer in Air Force undergraduate pilot training. Fairchild Republic Company and Garrett Turbine Engine Company have completed more than one year of full-scale development on the airframe and engine. The first test aircraft is scheduled to fly in fiscal 1985, and the first deliveries of production aircraft will be in 1986. The initial operational capability will be in 1987, and a total purchase of 650 aircraft is planned through 1992.

*VTXTS (Undergraduate Jet-Flight-Training System).* The VTXTS will integrate aircraft, simulators, academics, and a computer-based training integration system (for the dynamics of system operation) to train Navy and Marine Corps pilots in jet flight. It will replace the intermediate and advanced phases of the present jet training program. Turbofan technology and integrated hardware will enable the Navy to cut its cost to train a jet pilot by about one-half. McDonnell Douglas Corporation was awarded an initial development contract as the prime contractor in September 1982. In-depth analysis of program costs, including alternatives, and preparation of detailed specifications were completed in 1983.

*Remotely Piloted Vehicle (RPV).* The Army remotely piloted vehicle will perform target-acquisition, designation, aerial-reconnaissance, and artillery-adjustment missions. A small unmanned air vehicle, including its mission payload, is controlled from a ground station, and video imagery and target-location information are returned via a jam-resistant data link. In 1983, contractor system-integration tests were conducted to include integration of the data link and TV

sensor. Software certification was completed and flight tests resumed. Twenty soldiers were trained to operate the system, and a soldier-operated capability was activated at Ft. Hood, Texas, in November 1983 for early concept testing.

### *Cruise Missile Programs*

*Air-Launched Cruise Missile (ALCM).* At the end of 1983, three B-52G aircraft squadrons were operational with the ALCM-B, and the Strategic Air Command was conducting follow-on operational test and evaluation. The ALCM is a key element in the Triad of U.S. land, air, and sea forces. It provides the bomber force weapon accuracy, flexible routing and targeting, reduced exposure to enemy defenses, and saturation of defenses. Initially, the B-52G aircraft are carrying 12 ALCMs loaded on two external pylons, while still retaining the internal capability of carrying short-range attack missiles and gravity weapons. Beginning in fiscal 1986, ALCMs will be loaded externally on B-52H aircraft. Future plans include internal loading of cruise missiles on the B-52Hs for a total of 20 missiles each. The B-1 will also be capable of carrying cruise missiles. A total of 1,475 missiles were under contract through 1983, with an additional 240 planned for 1984.

*Ground-Launched Cruise Missile (GLCM).* In December 1979, the NATO ministers agreed to deploy the GLCM and Pershing II to counter Soviet modernization and to pursue arms control negotiations with the Soviet Union. The Air Force GLCM can survive an enemy first strike and has a very long range and thus will help offset opposing numerical superiority in both conventional and nonstrategic nuclear forces.

GLCM completed its development and initial operational flight testing in July 1983 with seven successful flights, two partial successes, and one failure. Production assets were deployed to Greenham Common, United Kingdom, in late 1983, and initial operational capability was achieved in December 1983. The deployment plan, unless altered by arms talks, calls for 464 missiles based in five European countries by 1988.

*Sea-Launched Cruise Missile (SLCM).* The SLCM is a key element in the Navy's tactical and strategic weapons inventory. The Harpoon weapon system is operational with the U.S. Navy, extending the range for antiship attack by submarines, surface ships, and aircraft. During 1983, Harpoon installation continued on U.S. Navy ships and submarines.

The Tomahawk SLCM provides both land-attack and antiship cruise missiles sized to fit torpedo tubes and can be launched from submarine and surface platforms against land and surface-ship targets. The antiship Tomahawk missile (TASM) can deliver a conventional warhead against heavily defended surface combatants at extended ranges. The land-attack Tomahawk missile (TLAM) can carry either a conven-



tional or a nuclear warhead and provides Navy operating forces a distributed strike capability with survivability. During 1983, developmental and operational testing of the TASM and TLAM was conducted at Pacific Missile Test Center, Point Mugu, California, and fleet capability for TASM was achieved on U.S.S. *New Jersey* (BB-62) and U.S.S. *Atlanta* (SSN-712).

**SH-60B Seahawk.** The Navy received the first production SH-60B Seahawk helicopter, a derivative of the Black Hawk helicopter, to serve as the airborne platform for the LAMPS MK III antisubmarine weapon systems. At the end of the year, the Navy was awaiting approval to begin development of the SH-60F to replace the aging SH-3H Sea King, which provides close-in antisubmarine protection for the battle groups.

**HH-60D Night Hawk.** The Air Force began full-scale development in late 1982 of a night and adverse-weather version of the Army UH-60A for combat rescue and special operations. Congressional concern about the Air Force requirement and total cost resulted in restructuring the 243-aircraft, \$5-billion program to a 155-aircraft, \$2.8-billion program to field 69 night and adverse-weather HH-60Ds and 86 night-visual-condition HH-60Es. Production is scheduled to begin in 1986 with initial operational capability in 1988.

**CH-47 Modernization.** Ceremonies at Ft. Campbell, Kentucky, February 28, 1983, marked delivery of the first CH-47D medium-lift helicopter. The receiving unit already had 100 percent of its initial requirement of spares, repair parts, and organization tools, and its maintenance and training cadre were fully qualified. Fielding continued throughout 1983 and will be completed for the first tactical unit in February 1984. Prototype CH-47Ds flying at Ft. Campbell and at other U.S. Army stations continued to demonstrate improved performance and reliability. A production contract to modernize 24 additional CH-47 helicopters was awarded on September 30, 1983, and one to modernize 36 more is planned for 1984. Eventually a total of 436 CH-47s will be modernized.

**MH-53E.** The Navy is developing a version of the H-53 helicopter, the MH-53E, for airborne mine countermeasures. The project is to provide an airborne platform that can tow equipment to counter large, sophisticated mines capable of paralyzing naval and commercial shipping. A contract was signed in 1982, and the project is scheduled for completion in 1984. During 1983, a production prototype helicopter was fabricated and development continued for mission-equipment provisions and airframe modifications. The helicopter flew its first flight in September, and flight testing began.

**AH-64 Apache Advanced-Attack Helicopter.** The Apache development, the Army's number one aviation program, will provide a lethal antitank capability 24 hours a day. Armed with a laser-guided Hellfire missile, the Apache provides significant improvements in tank-

destruction ability over existing systems. The first production helicopter rolled off the Mesa, Arizona, final assembly line on September 30, 1983, two months ahead of schedule. Flight test began in November, and the first production aircraft is scheduled for February 1984 delivery to the Army.

#### *V/STOL Programs*

**AV-8B.** The AV-8B for the Marine Corps is an improved, vectored-thrust, vertical or short takeoff and landing (V/STOL) aircraft based on the AV-8A aircraft and the Pegasus 11 engine. It will provide up to twice the range or payload performance of the AV-8A with improved reliability and maintainability. Flight testing of four full-scale development aircraft is two-thirds completed and includes some 1,000 hours of flying, six dedicated Navy development periods, and four initial operational test and evaluations. A Navy limited production review in July 1983 approved the fiscal 1983 procurement and long-lead commitments for 1984. The first of 328 production AV-8Bs was delivered as scheduled.

**Joint Services Advanced Vertical-Lift Aircraft (JVX).** The Navy in late 1982 was designated the executive service for the joint program developing a vertical-lift (tilt-rotor) JVX aircraft using advanced, but mature, technology to provide the USMC, USN, and USAF a self-deployable, multimission V/STOL for the 1990s and beyond. The JVX is to satisfy operational requirements for Marine Corps assault vertical lift, Navy combat search and rescue, and Air Force special operations.

The preliminary design phase began in April 1983 to define the scope, risk, cost, and schedule of full-scale development starting in fiscal 1985. It will substantiate the JVX design; discover and reduce potential technical problems early in the program; reduce technical and schedule risks; and study design tradeoffs among operational requirements, design criteria, and configuration variations. A 23-month contract awarded to the team of Bell-Boeing April 15, 1983, includes wind-tunnel testing to determine aerodynamic performance characteristics, piloted flight-simulation testing, construction of selected subsystem mockups, avionics definition, critical structure testing, and technical and support tradeoff studies. The Marine Corps is to reach initial operational capability in mid-1991, with aircraft for other services expected by 1993.

#### *Aeronautical Research and Development*

**X-29 Advanced Technology Demonstrator.** A joint DARPA-USAF-NASA program continued development of advanced aerodynamic, structural, and flight control technology integrated in a forward-swept-wing experimental aircraft. The first X-29 aircraft was assembled and began extensive ground testing at



Grumman Aerospace Corporation for a first flight in mid-1984. The X-29 is an advanced-technology demonstrator similar in size, weight, and performance to Northrop's F-20 Tigershark aircraft. Final design and fabrication began formally in January 1981, following four years of preliminary design analysis and structural and aerodynamic testing.

*Advanced Fighter Technology Integration (AFTI).* The Air Force AFTI test aircraft integrates a triple-redundant, digital-flight-control system with canard control surfaces to achieve independent six-degree-of-freedom control, improving agility and flexibility. Flight tests began in 1982, and investigation of the new flight control features and handling qualities was completed in August 1983. During the second phase of the program, beginning February 1984, the advanced system will be integrated with a fire control system and new infrared sensor and tracker for highly accurate maneuvering attack at very low altitude. Technology demonstrated in the AFTI program will be used to improve the performance of future fighter aircraft.

*Rotorcraft System Integration Simulator (RSIS).* The Army is developing an aviation-engineering-research simulator in a joint program with NASA. The Rotorcraft System Integration Simulator (RSIS) will enable the Army and NASA to simulate rotorcraft flight dynamics, providing information for developing helicopters, for validating system designs, and for aircraft improvements. The RSIS will help solve many problems in flying qualities, system integration, and weapon system effectiveness on rotorcraft. The Army also will formulate a software package for potential use in all flight training simulators, from the aircraft engineering software developed in the RSIS program. The RSIS demonstration and validation will be completed in 1986.

*Army's Aeronautical Technology Research.* The Army conducts exploratory development and aeronautical research, in house and under contract, to increase operational effectiveness of helicopters, reduce life-cycle costs, improve availability, reduce vulnerability, and improve flight simulation and analysis of helicopter system integration. Disciplines include aerodynamics, structures, propulsion, reliability and maintainability, safety and survivability, aircraft subsystems, mission support, flight simulation, and man-machine integration. During 1983, work included accomplishments across a wide range of technology.

The Army began a technology development program entitled Advanced Rotorcraft Technology Integration (ARTI) in support of full-scale development in early fiscal 1987 of a family of light helicopters (LHX). Previous research demonstrated that a highly integrated and automated cockpit and associated electronics could improve communications, navigation accuracies, and weapon system management and reduce target-acquisition times and pilot work load. The ARTI program is to develop the design requirements

and system specifications for an advanced integrated and automated cockpit and associated electronics and to determine the practicality of a single crew member with the rapidly emerging electronic technology.

ARTI phase I contracts were awarded at the end of December 1983 for LHX mission analysis, cockpit and architecture system design and fabrication, flight simulation, and flight test. These efforts will result in recommended design requirements and system concepts for LHX development. A follow-on competitive procurement in late 1985 is anticipated for an ARTI phase II, which will investigate incorporating projected 1992 technology into the advanced integrated and automated cockpit for future Army rotorcraft. Preplanned product improvement for the LHX will also be studied.

*Advanced Digital-Optical Control System (ADOCS).* The ADOCS program is providing the technology base for engineering development of a battlefield-compatible flight control system to improve aircraft handling and decrease pilot work load. Component development programs, control-media mechanization studies, and advanced-actuation concept studies feed into the ADOCS flight-demonstration program, which will evaluate the performance of the system. The ADOCS will be installed in a UH-60A for flight testing to verify development, progress, and handling improvement. The goals are to demonstrate the feasibility of control solely by optical signal paths with no degradation in performance below that of mechanical flight control systems, to provide data for future production of digital-optical control systems, and to provide handling qualities and control laws for the ADOCS.

The ADOCS flight-demonstration program, awarded to Boeing Vertol in 1981, had completed about 80 percent of the detailed design phase at the end of 1983, with flight testing scheduled for completion in June 1984.

*Air Mobility.* The Army plans and carries out basic research in aerodynamics specifically for rotor systems, rotary-wing and V/STOL aircraft, advanced propulsion systems, and development of materials, structures, and aviation electronics that enhance the survivability, mission effectiveness, and safety of future Army aircraft. Accomplishments in 1983 were made in each of the technology areas of aeromechanics, propulsion, structures, mathematics, and electronics—particularly in materials, aerodynamics, and aviation electronics. To support future helicopter designs, durability data was obtained from primary and secondary structures of Bell 206L helicopters flown more than 8,500 hours in a wide variety of weather conditions.

Another group of independent researchers developed innovative techniques and analytic procedures resulting in the first clear understanding of the mechanisms responsible for impulse noise generated by helicopter rotors. This work also established the validity of scaling laws to permit extrapolation from

small-scale to full-scale rotors. In still another research area, several methods of constructing single-mode, coherent, 10.6-micrometer fibers were explored to support the carbon dioxide-heterodyne laser systems being developed for obstacle avoidance, terrain following, and Doppler navigation. The fiber will significantly reduce the heavier, bulkier optics in present systems, permitting placement of the laser at various locations within the aircraft.

*Advanced Composite Airframes.* The Advanced Composite Airframe Program (ACAP) established the design data, fabrication experience, and test experience for using advanced composite materials in primary and secondary airframe structures of helicopters. Two competitive contracts with Bell Helicopter and Sikorsky Aircraft provide a broad base of technology development, with participation of major subcontractors from the fixed-wing industry—Grumman Aerospace, Vought Corporation, and Hercules Inc. The contractors developed a computer-aided design and manufacturing capability that has saved significant design and analysis time over that of conventional techniques.

ACAP designs include the most complete and advanced military requirements (crashworthiness, ballistic tolerance, radar cross-section reduction) yet attempted for a helicopter airframe and have provided criteria and substantiating test data for critical interface with aircraft components and subsystems. The Bell ACAP aircraft will use components from the Bell model 222 commercial helicopter; the Sikorsky ACAP aircraft, components from Sikorsky's commercial S-76.

Fabrication of the static test airframe and the flight test vehicle has begun. Static and dynamic testing of the airframe and assembly of the test vehicle with operational components will begin in 1984, with flight tests later in 1984 and completed in 1985.

*Avionics.* The avionics program in 1983 included an award of a joint Air Force-Army advanced development contract for future multiband digital avionics of the Integrated Communication, Navigation, Identification Avionics (ICNIA) program. Developmental and operational testing was completed on an inertial navigation system (AN/ARC-132) for improved navigation of Army helicopters. The electronics for the light helicopter (LHX) family of helicopters was examined in great detail in 1983. Sufficient technology will exist to give serious consideration to a single-crew-member configuration in the LHX. Extensive efforts will continue in 1984. Testing of an army digital avionics system (ADAS), which has a very good potential for the LHX, included verifying the adequacy of the software. ADAS flight tests will begin in early 1984. A digital map generator and voice-interactive capability will be integrated in prototype form in 1984, to be followed by airborne testing.

The Air Force was designated the lead service for the DoD microwave landing system (MLS) project in

January 1983. In August 1983, a triservice-coordinated DoD MLS implementation plan was adopted. Fixed-based MLS equipment for DoD is to be procured through the Federal Aviation Administration beginning in fiscal 1987. Plans are to evaluate integrating GPS user equipment with MLS avionics.

*Joint-Technology Demonstrator Engine (JTDE).* A joint USAF-USN program demonstrates advanced propulsion technology in full-scale, realistic operating environments, substantiating performance, structural integrity, and reliability. The program provides a technology base for correcting fleet problems, operating existing systems, and developing new engines. The technology accepted for tests is derived from USAF, USA, USN, NASA, and contractor efforts. Significant during 1983 were the demonstration of the General Electric Company's variable-cycle engine, transonic and supersonic compressor system demonstration, verification of life of single-crystal turbine blades, and demonstration of advanced superalloys in augmentor flameholders.

*Multiple-Application Core Engine.* A joint Navy-Air Force program identifies, analyzes, and designs (preliminary design) propulsion systems for future use. The prime effort is to identify the minimum number of cores to satisfy advanced propulsion requirements through the year 2010 and beyond. Thirty systems have been studied (USN and USAF), and detailed preliminary design is complete for the first application, the joint advanced fighter engine (JAFE). The first year of funding for JAFE was fiscal 1983, and the Air Force is proceeding with competitive development of two prototype demonstrators of this core engine.

*Lightweight Hydraulic System.* Investigation continued in 1983 on a lightweight hydraulic system as one candidate for reducing weight in future aircraft. Reduction in subsystem weight has increased in importance with the increasing hydraulic power requirements in complex aircraft such as the F-14, the reduced space availability in aircraft such as the F/A-18, and the need for minimum weight in V/STOL aircraft such as the AV-8B.

Naval Air Development Center investigation of the lightweight hydraulic system culminated in a laboratory system simulating an aircraft installation. This simulator is in operation, with more than 400 test hours on actuators, pumps, and related subsystems. The end result of the simulator phase will be flight-worthy hardware to be test flown in an A-7 aircraft. Design analysis, using test results, indicates that, for typical carrier-based tactical aircraft, 30 percent of the weight and 40 percent of the volume of the total hydraulic system can be saved.

*Maneuvering-Flight-Path Display System.* A significant accomplishment in 1983 was the feasibility demonstration of a new all-weather flight-guidance-display concept integrating all guidance information into a single "highway in the sky" which the pilot follows. Reference

data (altitude, airspeed, etc.) can be provided on the display in accordance with pilot needs. The system, which requires extensive computational capability to maintain real-time path guidance, was installed in the Air Force's total inflight simulator (TIFS) aircraft to assess effectiveness. Future efforts will be directed to extending its application to combat maneuvering, low-altitude terrain following, and avoidance of surface-to-air missiles in all weather conditions.

*XV-15 Tilt-Rotor Research Aircraft.* The XV-15 tilt-rotor research aircraft—the product of several years of technology development managed by a joint NASA-Army Project Office team at the Ames Research Center, Moffett Field, California—continued to make progress in 1983, with the Navy and Marine Corps evaluating the tilt-rotor concept for a number of operational uses. Air-combat maneuvering tests at Yuma, Arizona, helped defined conditions that may be encountered during aerial combat. Modifications in both test aircraft were made to improve and refine flight handling, including modifications of the roll-and-pitch stability-and-control augmentation system. Flight evaluations expanded the flight envelope and improved understanding of pilot work load and aircraft controllability. The aircraft was shown at a variety of airshows, including the Naval Air Station Moffett 50th Anniversary Airshow July 2-4, 1983. The concept of the XV-15 has been proved, and further studies are investigating uses, such as in the special-electronic-mission aircraft role for the Army.

*X-Wing.* During 1983, rotor system design and basic design data were completed and modification and subsystem fabrication begun for the DARPA X-wing, an innovation in vertical takeoff and landing (VTOL) aircraft design that combines the vertical lifting efficiency of a helicopter with the speed, range, and altitude performance of a transonic fixed-wing aircraft. This novel concept has been tested in wind tunnels and whirl towers, and a rotor will be flight-tested in fiscal 1985 in a joint NASA-DARPA program. The X-wing operates as a rigid rotor helicopter that uses circulation control instead of blade pitching for lift and control. When aloft, the X-wing aircraft converts to a fixed-wing configuration in forward flight. The rotor is stopped and the blades become fixed elements swept both forward and aft, and the aircraft will be capable of high subsonic speeds.

## **Space and Aeronautics Support**

### *Satellite Control Facility (AFSCF)*

The Air Force controls satellites for DoD from the Satellite Test Center (STC) at Sunnyvale, California, a worldwide network of seven tracking stations. During 1983, the network supported 27 launches, including 9 DoD and 11 NASA orbital missions and 7 ballistic flight tests. Of special note was support by the

AFSCF and its New Hampshire tracking station for the sixth Shuttle mission, sending commands to the spacecraft to separate the inertial upper stage from the Tracking and Data Relay Satellite and saving that mission.

The data-system modernization program continued development, with operations scheduled to begin at both the Satellite Control Facility and the Consolidated Space Operations Center in 1986. The new system will form the core data-processing system for this evolving Satellite Control Network. Development of the Advanced Remote-Tracking Station began with the late 1983 release of a request for proposals to replace or refurbish the existing remote tracking stations and complement data system modernization.

### *Consolidated Space Operations Center (CSOC)*

May 1983 ground-breaking marked the beginning of construction of the CSOC facility near Colorado Springs. On completion, CSOC will consist of two major elements: the Satellite Operations Complex and the Shuttle Operations and Planning Complex. The satellite control capability is needed because of the vulnerability and severely limited growth capacity of the present Air Force Satellite Test Center. The Shuttle control capability is needed because DoD plans to rely on the Space Shuttle for its missions. CSOC will overcome limitations of interim Air Force Shuttle control facilities at NASA's Johnson Space Center by providing a secure environment from which to conduct space missions, a site to minimize environmental and man-made hazards, adequate capacity to support the expected Shuttle traffic, and the capability to conduct military space operations from dedicated DoD facilities. CSOC and the present Satellite Test Center will provide mutual backup for satellite control, while CSOC and Johnson Space Center can provide mutual backup for Shuttle control.

Facility construction is planned for completion in 1985. The first satellite mission control center will be operational in 1986, with additional centers activated in 1987 and 1988. To support the DoD Shuttle flight schedule, the CSOC Shuttle Flight-Planning Element will become operational in 1987. The Shuttle Flight-Readiness and Flight-Control Elements will be activated in time to provide a year of crew training, rehearsals, and active flight (in parallel with NASA control operations) to validate CSOC operational readiness before the first CSOC-controlled Shuttle flight.

### *Eastern Space and Missile Center (ESMC)*

ESMC, at Patrick AFB in Florida, provides launch, range-safety, and data-acquisition support for developmental and operational test launches of ballistic missiles of the Navy's Poseidon and Trident fleet, Army's Pershing I and II missiles, and Air Force's

short-range attack missile (SRAM). ESMC also supports low-inclination-orbit DoD, NASA, and NASA-sponsored space programs. During 1983, ESMC supported 11 major space test operations, including the first flight of the European Spacelab aboard Space Shuttle *Columbia* in November.

#### *Western Space and Missile Center (WSMC)*

WSMC, at Vandenberg AFB in California, provides launch, range-safety and data-acquisition support for development and operational test launches of Minuteman and Peacekeeper missiles and for DoD and NASA space programs requiring polar orbit. The cruise missile and B-1B bomber dominated the aeronautical tests supported during 1983. Construction of the Space Transportation System's Western Launch Site continued at a fast pace. In 1983, WSMC supported 11 major space test operations and the first 2 launches of the Peacekeeper (M-X) missile.

#### *White Sands Missile Range (WSMR)*

WSMR, White Sands, New Mexico, continued to support DoD and NASA aeronautics and space programs in 1983. NASA programs supported were the Space Shuttle, upper atmospheric sounding by rockets and balloons, and a variety of astronomical test programs. Launch and flight recovery services included ground and flight safety, range surveillance, command and control as needed, and data acquisition and analysis. Space Shuttle activities at WSMR include qualification tests on the orbital maneuvering system and on forward and aft reaction control systems, evaluation of Shuttle spacecraft materials, training of astronauts to land the Shuttle, preparation of a satellite system to track and relay Shuttle data back to earth, and Shuttle flight and landing support. WSMR continues to maintain readiness for Shuttle landings, including training of chase aircraft pilots for rendezvous, tracking-acquisition tests, data-transmission tests, and support system operations.

#### *Kwajalein Missile Range (KMR)*

Kwajalein Missile Range continued support to DoD and other users, as the major test range for defensive missile forces and terminal-area testing of strategic missile forces. Activity at the range increased during 1983 with the initiation of a major Ballistic Missile Defense flight experiment, the Homing Overlay Experiment, and the start of Peacekeeper (M-X) flight testing. The increased pace is expected to continue in the year to come. KMR is unique in that there is no other comparable U.S. facility to collect signature data on objects outside the earth's atmosphere, record missile reentry phenomena, provide terminal trajectory and impact data, recover reentry vehicles, and transmit nearly immediate data to mission sponsors.

The data collected on nearly all KMR missions met requirements of both strategic offensive and defensive developmental communities, for mutual accomplishments of test objectives and continuous interchange of data at a significant saving in costs.

#### *Arnold Engineering Development Center (AEDC)*

AEDC at Tullahoma, Tennessee, participates in developing and continuing the operational effectiveness of advanced-technology aerospace systems by conducting tests, engineering analyses, and technical evaluations. A national facility with both government and commercial users, AEDC over the past year supported such projects as the Peacekeeper, Space Shuttle, B-1B, F-16, F-100 engine, next-generation trainer, and advanced medium-range air-to-air missile. AEDC operates and maintains some 25 aerospace ground-test facilities, which provide aerodynamic, propulsion, and spaceflight environment simulations.

#### *Air Force Flight Test Center (AFFTC)*

AFFTC, at Edwards AFB in California, conducts development tests and evaluations of manned and unmanned aircraft systems, aerospace research vehicles, and aerodynamic deceleration devices. Tests range from engineering simulations before flight through flight tests of fully integrated weapon systems. The large air space, dry lake beds, isolation, and highly instrumented ranges provide a unique support capability for many users including three major tenants—NASA's Dryden Flight Research Facility, Army's Aviation Engineering Flight Activity, and Air Force Rocket Propulsion Laboratory. During 1983, the center supported space, tactical, and strategic systems including the Space Shuttle, F-15, F-16, F-16XL, advanced fighter technology integration (AFTI), F-20, B-52 integrated weapon system, KC-135R, and air- and ground-launched cruise missiles.

#### *4950th Test Wing*

The 4950th Test Wing, an Air Force Systems Command (AFSC) unit based at Wright-Patterson AFB, Ohio, flight-tests military systems, subsystems, and components. It operates and modifies test and test support aircraft and is the AFSC test organization responsible for Class II aircraft modification policy. One of its primary support aircraft is the advanced range-instrumentation aircraft (ARIA), which serves key telemetry, data-processing, and command-control functions during both aeronautical test flights and space missions. A major project is improving ARIA capabilities by converting from the existing C-135 to C-18 (Boeing 707) aircraft while concurrently updating installed data-acquisition equipment.

## Relations with NASA

### *Aeronautics and Astronautics Coordinating Board*

The Aeronautics and Astronautics Coordinating Board (AACB), cochaired by the Under Secretary of Defense for Research and Engineering and the NASA Deputy Administrator, is the major forum for review of policy and programmatic issues of mutual DoD and NASA interest. Its active panels complement the interagency coordination process. During 1983, the AACB met twice (the 89th and 90th meetings), taking up subjects related to the Space Transportation System and to aeronautics. As a result of the 90th meeting, the board began NASA-DoD preparation of a Space Transportation System long-range planning document. The document will be reviewed annually to assist in budget planning and program review.

### *Cooperative Programs*

DoD—through the Army, Navy, Air Force, and Defense Advanced Research Projects Agency—continued research and development programs with NASA in space and aeronautics technology. A NASA-

USAF program continued to develop components for a satellite communications system in the 20-GHz-frequency range. The Navy—with NASA, NOAA, and Air Force support—will develop the Navy Remote Ocean Sensing System (*N-ROSS*), an oceanographic satellite to provide tactical information to operating forces.

Major joint efforts continued toward a fully operational Space Transportation System, including the Space Shuttle, inertial and Centaur upper stages, launch and landing facilities at Kennedy Space Center and Vandenberg AFB, and mission control elements at Johnson Space Center, Goddard Space Flight Center, and the Consolidated Space Operations Center to be located near Colorado Springs. And in 1983 NASA and DoD completed assessments of requirements for a Space Station.

DoD and NASA continue to support each other in expendable launch vehicle operations and spaceflight opportunities for technology development experiments. Cooperative aeronautical activities include wind-tunnel and flight-test support for aircraft technology development discussed in the preceding text.



# Department of Commerce

Department of Commerce agencies participating in the nation's aeronautics and space program during 1983 were the National Oceanic and Atmospheric Administration (NOAA), National Bureau of Standards (NBS), and National Telecommunications and Information Administration (NTIA).

NOAA's mission is to ensure the safety of the public and improve the quality of life through better understanding of the earth's environment and more efficient use of its resources. It operates the nation's civil operational environmental satellite systems, using their data to assess the effect of natural factors and human activities on global food and fuel supplies and on environmental quality; to observe and forecast weather conditions, provide warnings of severe weather, and assist community-preparedness programs for weather-related disasters; to prepare charts and coastal maps for geodetic research; to improve assessment and conservation of marine life; to meet the needs of public and private users including scientists; and for research to improve the nation's environmental monitoring and warning service.

The National Bureau of Standards maintains and develops national standards of measurement and provides government, industry, and academia the measurement services and fundamental physical, chemical, and engineering data to achieve national goals. NBS supports space systems, atmospheric and space research, and aeronautical programs.

The National Telecommunications and Information Administration is the principal telecommunications adviser to the President. It develops and coordinates executive branch policy in telecommunications and information. NTIA also is responsible for managing the radio spectrum assigned for federal use, providing technical support to international telecommunications conference activities, and providing technical assistance in telecommunications matters to other federal agencies.

## Space Systems

### *Satellite Operations*

**Polar Orbiting Satellites.** At the end of 1983, the operational, polar-orbiting weather satellites were *NOAA 7* and *NOAA 8*, orbiting the earth about the poles in sun-synchronous orbits and providing environmental

observations of the entire earth four times each day. *NOAA 7* crosses the equator northward at 2:30 p.m. local time, and *NOAA 8* crosses in a southward direction at about 7:30 a.m. These satellites carry four primary instruments: the advanced very-high-resolution radiometer (AVHRR), the Tiros operational vertical sounder (TOVS), the Argos data-collection and platform-location system (DCLS), and the space environment monitor (SEM).

*NOAA 8*, launched in March 1983, is the first in a series of new Advanced Tiros-N (ATN) spacecraft and carries additional instruments for search and rescue (SAR). *NOAA 6*, the former operational morning-descending spacecraft, was placed on standby and is planned for deactivation by April 1, 1984.

**"NOAA-Next."** Planning was completed for purchase specifications for a NOAA-series of low-orbit, polar-orbiting meteorological spacecraft for the 1990s. Plans include providing the capability for launching on the Space Transportation System (Shuttle).

**Geostationary Satellites.** *GOES 5* and *6* were the operational satellites in NOAA's Geostationary Operational Environmental Satellite system at the end of 1983. *GOES 6* was launched on April 28, 1983, and on June 1 replaced *GOES 1*, which by then could provide only visible imagery. In orbit at about 35,000 km above the equator, *GOES 6* is at 135° west longitude, and *GOES 5* is at 75° west. Both are equipped with the visible-infrared spin-scan radiometer (VISSR) atmospheric sounder (VAS).

The VAS relays traditional images of the earth's surface and cloud cover, as well as thermal images of atmospheric temperatures and the water vapor content at various altitudes. Its 12 infrared channels provide temperature and moisture profiles in noncloudy areas at a much higher viewing frequency than can balloon soundings or polar-orbiting satellites. The *GOES 5* and *6* operational demonstration program so far indicates that the VAS capability is excellent, and a ground system is being developed to use VAS data to improve NOAA's operational weather analysis and forecasting. *GOES* satellites also carry a space environment monitor, a data-collection system, and a weather-facsimile broadcast service. Other in-orbit spacecraft (*GOES 1*, *2*, *3*, and *4*) remain on standby, providing limited operational support for weather facsimile and data collection.

*"GOES-Next."* After almost two years of joint studies by a NOAA-NASA team, purchase specifications were completed (July 14, 1983) for the next generation of GOES satellites. NASA, acting for NOAA, will purchase "GOES-Next" satellites for flight during the 1990s. Improvements include concurrent imaging and atmospheric sounding (not available with present GOES), additional information for atmospheric movement of water vapor, and relocation of picture elements, to permit better calculation of winds from images showing cloud motions.

*Land Satellites.* NOAA, authorized to manage an operational land satellite system based on the Landsat D and D' satellites constructed by NASA, assumed operational responsibility for the first of these satellites January 31, 1983. NASA had launched Landsat D (renamed *Landsat 4* after achieving orbit), on July 16, 1982, and completed the operational testing of the satellite in November. NOAA established a technical staff at Goddard Space Flight Center in 1982 to manage the day-to-day operation of the *Landsat 4* system.

*Landsat 4's* operational instrument, the multispectral scanner (MSS), measures reflected solar radiation over four bands of the visible and near-infrared wavelengths at 80-meter resolution. Its experimental thematic mapper (TM) measures radiation over six bands in the visible and near-infrared wave-lengths at 30-meter resolution and one band in the thermal-infrared wave-length region of 11 micrometers at 120-meter resolution. MSS data are available for most of the contiguous United States, Alaska, most of Central and South America, northern Europe, the northwest Soviet Union, Japan, and near neighboring areas of Asia and Australia. Limited, unscheduled TM data are available for the contiguous United States and Canada. Data are distributed through the Department of the Interior's Earth Resources Observation System (EROS) Data Center in Sioux Falls, South Dakota, and through foreign facilities in countries with Landsat ground stations (Canada, Brazil, Argentina, Sweden, Italy, South Africa, India, Australia, Japan, and Thailand). *Landsat 5* (called Landsat D' before launch) is scheduled to be launched March 1, 1984, to replace *Landsat 4*.

During 1983, NOAA continued its agreement with the EROS Data Center for production, distribution, and archiving of Landsat products. NOAA had assumed this responsibility in October 1982, including data products from *Landsat 1*, *2*, and *3*. The prices of products are set with the intention of recovering the cost of operating and managing the Landsat system.

#### *Satellite Data Services*

*GOES-Tap.* Customers of the GOES-Tap system, which became operational in 1975 to disseminate weather satellite images over telephone circuits, con-

tinued to increase. The original 50 Weather Service Forecast Office Taps increased by the end of 1983 to about 225 GOES Taps.

*WEFAX.* The Goes Weather Facsimile (WEFAX) broadcast schedules were expanded on the operating satellites to make 357 daily broadcasts of satellite imagery sectors, meteorological analyses and prognoses, and operational and ephemeris messages. Known users totaled 192, with 92 of them domestic and 100 non-U.S. In June, the first International Direct Broadcast Services Users' Conference was held in the Washington, D.C., area. Nearly 400 attended, including representatives from several foreign meteorological agencies, academia, industry, and amateur enthusiasts interested in WEFAX and other direct readout services provided by NOAA-operated spacecraft.

*DCS.* The GOES Data Collection System (DCS) relays almost immediate environmental data from remotely located data-collection platforms. At the end of the year it had more than 4,300 platforms, an increase of 700 during the year. Data goes to 78 national and some 950 international users and 21 direct readout stations. GOES DCS reliability has been in excess of 99 percent during the year. The Random Reporting Operating Mode was operationally tested for 18 months, with the U.S. Army Corps of Engineers and the Bureau of Reclamation participating, and NOAA was expected to adopt this mode of operation within the next few months. The present NOAA ground system is expected to reach saturation sometime during calendar year 1984, when 5,000 platforms will be in the system. NOAA and several federal user agencies are examining joint funding of an expansion or replacement of this ground system. A comprehensive description of the GOES DCS was published in June as NOAA Technical Memorandum NESDIS 2.

*Radiofax.* NOAA expanded its radiofax service to more areas to provide more and better information to marine interests. A new service designed to provide all marine interests operating in the Gulf of Mexico with weather and oceanographic data began on January 1, 1983. Facsimile charts generated by NOAA's Ocean Service Unit in Slidell, Louisiana, are transmitted via phone line to Mobile Marine Radio, Inc. (WLO), in Mobile, Alabama, for broadcast to mariners. Oil interests, fishermen, commercial shipping, and yachtsmen all benefit from the new service.

*Dissemination of Satellite Imagery.* In 1983 a prototype device, the satellite imagery acquisition via telephone terminal (SIATT), was placed in operation at the Chattanooga Weather Service Office. With the device, small Weather Service Offices with weather warning responsibilities can, for the cost of a 10-minute long-distance telephone call, receive high-resolution GOES satellite imagery almost as fast as weather changes occur.

*Geophysical Data Base.* The National Geophysical Data Center archives, analyzes, and publishes data on the solar-terrestrial, geomagnetic, and cryospheric environments. The archive of visual and swath imagery for the Defense Meteorological Satellite Program (DMSP) was transferred from the University of Wisconsin to the center. This collection of Department of Defense and Air Force imagery shows cloud patterns and the distribution of snow and ice cover. A new satellite, *DMSP F-6*, became operational in early 1983, and auroral imagery and precipitating-charged-particle data from it are sent to the center. *DMSP F-6* also carries a new scanning auroral x-ray sensor that can record data during daylight as well as in darkness. The center, Aerospace Corporation, and USAF staff are discussing technical cooperation to integrate this new data base into the other DMSP archives and to derive new products from it. Another DMSP satellite was launched in late 1983.

Satellite data from U.S., European, and Japanese space agencies are being compared with results from the National Geophysical Data Center's analysis of ground-based magnetometer data. Computed electric fields, joule heating in the upper atmosphere, field-aligned currents, and ionospheric currents are being compared with instantaneous data from satellites passing through the critical regions. Ground-based magnetic and ionospheric data archived at the center are compared with magnetic field operations by the Magnetic Satellite *Magsat*, launched in 1979 and operated jointly by NASA and the U.S. Geological Survey. Calculations of total energy deposits from particle measurements by NOAA and Tiros satellites are made available from the center in cooperation with the Space Environment Laboratory.

*Satellite Data Base.* The Satellite Data Services Division of the National Climatic Data Center manages data collected by environmental satellites and the products that NOAA prepares from the data. The environmental satellite data base includes complete digital data from the present generation of NOAA's operational polar-orbiting and geostationary satellites, selected sensors aboard NASA's experimental *Seasat* and *Nimbus 7* satellites, and DMSP satellites, as well as a limited amount of digital data from earlier NOAA and NASA satellites. The volume of digital data is equivalent to more than 150,000 computer tapes and an additional 16,000 videocassettes of geostationary satellite data. The data base includes 10 million film images from 36 satellites, dating back to the first Tiros satellite launched in 1960. Each month in 1983 the equivalent of about 3,000 computer tapes, 150 videocassettes, and 15,000 images were added.

#### *Satellite Data Uses*

*Space Shuttle Support.* Weather support to the 1983 Space Shuttle flights was aided by the timely receipt of high-resolution 15-minute-interval imagery from a

GOES satellite. The NOAA Spaceflight Meteorology Group at the Johnson Space Center in Houston used the data extensively to monitor weather conditions for preselected recovery sites in the continental United States. The weather criteria for Shuttle landings are stringent, and the high-resolution imagery provided information not available from other sources.

*Airline Flight 007.* NOAA provided special satellite images and interpretations to the Department of Defense and other agencies supporting the investigation of the Korean Airlines Flight 007 incident over the Sea of Japan.

*El Nino.* The NOAA 7 AVHRR has been a vital tool for monitoring the 1982-1983 El Nino warm current in the Pacific Ocean. Developing somewhat atypically from past El Ninos (such as in 1956, 1968, 1972), this El Nino began during the summer of 1982, nearly six months out of phase. It also developed in the mid-tropical Pacific rather than along the South American coast. By late 1982, it spread eastward to the South American coastline in a fashion and severity not seen in the modern record. As warming developed in the mid-Pacific, west of the date-line, the satellite's measurement of sea surface temperature augmented the few ship reports of that temperature to provide an excellent record of the El Nino event. This El Nino produced positive temperature anomalies of 6° to 9°C off the Peru and Ecuador coasts during its peak (January, February, March, and April 1983). By summer 1983, the warm current seemed to be easing its grip on the eastern tropical Pacific. Although evidence was reduced in the satellite-derived measurement of sea surface temperatures because of atmospheric aerosol from the El Chicon volcano early in the El Nino episode, the surface development and evolution of the warmer water were better portrayed than they had been previously.

*Food Shortage Alerts.* NOAA developed and began testing a system that uses AVHRR data to improve existing operational alerts of drought-related food shortages for the Office of Foreign Disaster Assistance of the Agency for International Development (AID). The system monitors crop conditions using time-series index displays and a new color coordinate system for images to enhance the existing system, which uses surface reports and satellite rainfall estimates to monitor the potential for drought in 72 tropical countries.

*Global Mapped Vegetation Index.* NOAA has been funded by the AgRISTARS project to produce a global mapped vegetation index. AgRISTARS (Agriculture and Resources Inventory Surveys through Aerospace Remote Sensing) is a joint program of NASA, NOAA, and Department of Agriculture to evaluate the use of satellite data in providing crop estimates. The index depicts the extent and "greenness" of vegetation worldwide. Global AVHRR data are collected daily, and a vegetation index is computed and mapped to a polar stereographic projection. A weekly

composite vegetation index is produced from the daily data.

Polar, stereographic, mapped vegetation index products are provided in tape and image form to AgRISTARS for evaluation. In addition, other groups have expressed interest in the product, especially the United Nations Food and Agriculture Organization, and copies are available to any interested party. Production began in April 1982 and will continue at least through September 1984.

*Fisheries.* NOAA continues to use the *ATS 3* and Argos satellite communication systems to relay biological and environmental data from NOAA and state research vessels to shore stations for distribution to users. The data are a vital part of the Southeast Area Marine Assessment Program (SEAMAP), a cooperative state-federal program to improve the quantity, quality, and timeliness of fisheries data in the Gulf of Mexico. The satellite communications link permits state and federal fishery management organizations and fishing fleet operators to receive data from the research vessels within one day of collection.

As part of SEAMAP, NOAA developed a technique to use data from the coastal-zone color scanner (CZCS) flown on the NASA *Nimbus 6* satellite to chart hypoxic waters in the northern Gulf of Mexico. Hypoxic waters have very low concentrations of dissolved oxygen near the bottom and apparently form in response to phytoplankton blooms coupled with strong thermal stratification. The location of hypoxic waters is of concern to fishermen because these waters are almost devoid of finfish and shrimp. NOAA, NASA, and the Scripps Institution of Oceanography began providing nearly instantaneous CZCS data to NOAA for hypoxic water charts. NOAA also began developing instruments to measure dissolved oxygen in bottom water.

In cooperation with the University of Rhode Island, NOAA developed charts using NOAA 7 AVHRR data to depict thermal conditions on the continental shelf off the East Coast of the United States. The charts can guide fishermen to temperature fronts where surface and mid-water fish species tend to congregate. NOAA also continued the Coastal Habitat Assessment Research and Mensuration Program (CHARM), using Landsat multispectral scanner data to quantify changes in productivity, biomass, and areas of principal coastal-zone vegetation from North Carolina to Maine. A report on the classification of MSS imagery for the base year (1978-79) is available on request. A trial run to produce tables of statistics by state, county, and water catalogue unit proved successful. Tables for the entire area will be developed.

The development and improvement of techniques for visualizing and analyzing remotely sensed data continues. Techniques for clustering AVHRR and CZCS data proved useful in identifying ecologically coherent areas. Products illustrating these areas in the

Gulf of Maine-Georges Bank region were included in the Ecology Annex of the U.S. Counter Memorial on the Maritime Boundary Delimitation (Canada-United States of America), now in the International Court of Justice.

NOAA, the Scripps Institution of Oceanography, and Jet Propulsion Laboratory developed a cooperative program to distribute experimental sea-surface color charts to albacore tuna fisherman, directing fisherman to ocean color boundaries where tuna tend to aggregate.

*Hurricanes.* GOES satellite information was the key in NOAA's warning services for Hurricane Iwa's strike on the Hawaiian Islands in November 1982. Half-hourly picture interpretation at the Honolulu Satellite Field Services Station was the only information available for following the storm and was the basis for the hurricane warnings that helped keep the death toll to one, although damage in the heavily settled coastal areas totaled \$234 million.

GOES pictures were even more important in monitoring the unprecedented succession of tropical cyclones in the Pacific Ocean south of the equator. The Honolulu station followed a dozen storms during the Southern Hemisphere summer (November to May), issuing position and intensity bulletins to all affected weather centers in the South Pacific. Five of the storms were in the eastern area around Tahiti and the Society Islands, where a hurricane strike is considered a once-in-50-years event. Lives were lost and damage was much greater than in any previous tropical storm season. Satellite pictures provided the only information on the location of each storm, how intense it was, where and how fast it was moving, and whether it was curving back, strengthening, or weakening. Satellite imagery was similarly used by the Miami station to monitor hurricanes in the Atlantic Ocean. Operational support was provided to the Weather Service's National Hurricane Center.

*Snowmelt.* The National Environmental Satellite, Data, and Information Service (NESDIS) participated in the interagency "Snow Watch '83," monitoring the unusually heavy snowpack (150-300 percent of normal) in the Rocky Mountains and Sierra Nevada mountains. The runoff from melting snow flooded Salt Lake City and the Colorado River Basin in the spring of 1983. The Satellite Field Services Stations in San Francisco and Kansas City produced snow cover charts routinely for some 30 river drainage basins in the western United States, as often as once a day during rapid snowmelt, based on GOES and polar orbiter data. These charts were available to the Soil Conservation Service, Army Corps of Engineers, U.S. Forest Service, National Weather Service, Department of Energy, U.S. Geological Survey, and state water resource agencies, for predicting runoff. The San Francisco station also provides daily polar-orbiter im-



agery of selected portions of the Rocky Mountains on special request to the Weather Service.

On June 2, a press conference publicized the danger of flooding and demonstrated techniques used to monitor the snowpack. Examples of Landsat, polar-orbiter, and GOES imagery showed the heavy snowpack in various areas, as well as images from a normal year for comparison. Images were used in national and local news broadcasts, newspapers, and magazines. A video tape from GOES-East satellite imagery for the Colorado Rockies April 6 through July 5 clearly defines the snowmelt pattern that resulted in record flooding on the Colorado River.

*Rainfall.* NOAA continued to use GOES images to provide rainfall estimates for thunderstorms. The estimates supplemented rain-gauge observations and radar estimates during flash flood conditions. An improvement, the interactive flash-flood analyzer (IFFA), was made operational in July 1983, improving the timeliness and accuracy of the satellite estimates. These estimates are transmitted as events occur to the National Weather Service Forecast Offices responsible for flash flood watches and warnings. The IFFA replaces the manual technique of the past five years. Its speed of operation, coupled with rapid communications, combine to give field forecasters estimates of rainfall extracted from imagery before they receive the copy of the image in their office.

During the spring river breakups in Alaska, a large ice jam was observed on the Yukon River at the town of Circle. Satellite images permitted the River Forecast Office to alert the town of pending flooding, and no lives were lost. Usually river ice breakup is monitored by aircraft, which is costly; in this situation, the need for aerial reconnaissance time was minimized.

During 1983, work continued on categorizing and understanding the meteorology of subtle signatures of heavy rainfall in the satellite imagery. Work also continued on verifying an algorithm developed to predict convective precipitation by tracking cloudtops in the GOES images; this algorithm includes a fully automated precipitation-estimating technique. In addition, extratropical and tropical cyclone rainfall estimating techniques were developed and used operationally. The extratropical cyclone technique provided the National Weather Service with estimates of rainfall and snowfall from winter storms. The tropical cyclone technique provided the precipitation estimates (hourly rates and accumulated amounts).

*Forest Fires.* Large areas of fires in western Brazil, most likely associated with slash and burn agriculture and deforestation, were detected in visible imagery from NOAA polar-orbiting satellites. The main line of fires was 570 km long and the smoke area covered some 800,000 sq km.

Animated GOES images identify wind circulation patterns over mountainous terrain as far north as the Arctic Slope. Thunderstorm squall-line development

and movement can be observed, and the accompanying windshift and wind gusts can be predicted within one to two hours before they occur. The fire-weather programs have found this information invaluable in defining thunderstorms and large grass and forest fires in Alaska.

*Volcanic Eruptions.* NOAA polar-orbiting satellites monitored eruptions from Galunggung and Una Una volcanoes. The height of the plumes was determined from thermal data. Both eruptions clogged and stalled passenger aircraft engines, although the aircraft managed to restart their engines and land safely. As a result of these near-disasters, the Federal Aviation Administration formed an informal working group on volcano hazards to aviation. Early discussions indicate the need for an operational volcanic-hazards warning system with satellite data playing a major role. FAA will request NOAA participation in establishing the warning system.

During 1983, NOAA expanded its volcano reporting. As volcanic activity was observed by NOAA polar-orbiting satellites and GOES, information was sent to the Smithsonian Events Alert Network, the FAA, the World Vision Relief Organization, and NASA. A new NESDIS service provides data on observable phenomena such as volcanoes, hurricanes, and fires to NASA when Shuttle missions are in space. With this information, NASA photographic experts determine schedules for onboard photographs by astronauts.

NOAA satellite sightings of the eruption of the volcano on Ostrov Bennet in the Eastern Siberia Sea were reported to the CIA, NOAA Atmospheric Laboratory, and the University of Alaska's Geophysical Institute. In June, eruptions of the Veniaminof volcano near Perryville, Alaska, were reported to the U.S. Geological Survey, as well as to the FAA to permit rerouting aircraft around a potential ash plume.

*Ice Imagery.* Satellite imagery can locate the 5° isotherm and pockets of colder temperatures in Alaskan waters, critical to forecasting the severity of icing. In Alaskan waters, superstructure icing is a major problem for vessels of all sizes. Various agencies use special ice imagery in analysis products, forecasts, outlooks, and special operations and rescue efforts. Oil shippers also use the products to monitor ice conditions for shipping and drilling.

*Sea Fog.* Improvements in the accuracy of short-range forecasts of hazardous sea fog and information on dissipation are expected as a result of empirical studies relating changes in sea fog to changes in the surface wind flow and temperature patterns observed from GOES satellites and NOAA 7.

*Amazon Effluent.* During 1983, NESDIS satellites monitored changes in the effluent pattern of the Amazon River. The visible-band images noted the transport of sediment northward, paralleling the coast,



and confirmed earlier studies that relied solely on surface observations.

## Other Uses of Satellites

### *International Activities*

**Economic Summit.** The 9th Economic Summit of Industrialized Nations took place at Williamsburg, Virginia, in May 1983. NOAA coordinated U.S. preparation for discussions of expanding cooperation on satellite remote sensing within the framework of the Summit's Working Group on Technology, Growth and Employment. Discussions included increased international cooperation in meteorological satellite systems, land-satellite data products and archives, ocean satellite systems, remote-sensing research sensors, and remote-sensing training. The Williamsburg Summit endorsed the working group report and stressed the importance of further cooperation.

**International Satellite Land-Surface Climatology Project.** About 30 scientists, including 3 from NOAA, participated in the First Workshop to define the International Satellite Land-Surface Climatology Project (ISLSCP)—meeting in Boulder, Colorado, June 27–July 1, 1983. Initial funding for the workshop came from the United Nations Environment Program in connection with its responsibility for the World Climate Impact Program, but the World Meteorological Organization, International Association of Meteorology and Atmospheric Physics, and Committee on Space Research (COSPAR) of the International Council of Scientific Unions are also interested in the project in connection with the World Climate Research Program. The project will provide satellite data for monitoring changes on the land surface resulting from climatic variability or the actions of man and for improving climate models.

**Landsat Data Distribution.** Negotiations with foreign countries for direct reception and distribution of Landsat data continued, and several countries signed a memorandum of understanding with NOAA. The first NOAA-chaired meeting of the Landsat Ground Stations Operations Working Group (LGSOWG) was held in Washington, D.C., in November 1983.

**CGMS.** The Coordination of Geostationary Meteorological Satellites (CGMS) group met in April. Representatives from Japan, the European Space Agency (ESA), India, USSR, and the United States participated in plans to make the different meteorological satellite systems more complementary and compatible.

**International Satellite Cloud Climatology Project.** ISCCP is the first project of the World Climate Research Program, jointly sponsored by the World Meteorological Organization and the International Council of Scientific Unions, with U.S. participation coordinated by the National Climate Program Office. Satellites of

various nations, including NOAA's operational satellites, will gather visible and infrared radiance data. The data will be reduced and merged to produce a set of calibrated, global, radiance and cloud data for the international scientific community. Data collection began July 1, 1983. When completed, the cloud climatology will increase understanding of climate systems and improve climate forecasting. NOAA will provide the central archive for this data set.

**Satellite Soundings.** Satellite soundings in combination with conventional data, used by the operational numerical weather prediction model of the Israel Meteorological Service, reduced 48-hour forecast errors by 5 to 30 percent. Results varied and appeared to depend upon the synoptic situation, which may or may not be favorable for the effective ingestion of large quantities of new data. The largest and most consistent reduction in forecast error was over ocean regions where the satellite data were introduced. The use of satellite soundings without any conventional radiosonde data produced surprisingly good results, as good as and sometimes surpassing results from conventional radiosonde data.

**Argos.** The Argos data-collection and location system provided by France operates on present NOAA polar-orbiting satellites. More than 400 instrumented platforms (82 percent requiring location data) were operated by organizations from 17 countries at the end of 1983. Final amendments to the Argos agreement—under which the French National Center for Space Studies (CNES), NOAA, and NASA cooperate in satellite data collection—were agreed on, reflecting interest in continuing the program. Eleven countries, including the United States, concluded a joint tariff agreement for the use of the Argos system in 1983. The agreement allows a substantial reduction in the cost to signatory countries in exchange for a guaranteed level of use. The telephone concentrator at Suitland, Maryland (which gives users direct access to their disk files in Toulouse, France, without making a transatlantic telephone call), was being used by 40 platform operators at the end of the year. The French Coordination Center placed a full-time representative at Suitland to provide timely technical support to North American users.

### *Satellite Communications*

**Radio Conference.** The National Telecommunications and Information Administration (NTIA) is responsible for developing the federal government's proposals to the International Telecommunication Union (ITU), the United Nations specialized agency that establishes and administers international regulations concerning the use of the radio spectrum, including its use by spacecraft. In preparation for the ITU's 1983 Regional Administrative Radio Conference on broadcast-satellite service, which convened in Geneva in July, NTIA

participated in several bilateral and multilateral coordination meetings with conference planners from other administrations in the ITU's Region 2. (ITU Region 2 encompasses the Western Hemisphere and part of the Pacific Ocean area.) NTIA's Institute for Telecommunication Science (ITS) and its Office of Spectrum Management also conducted studies to assist in determining orbit-spectrum capacity and how this spectrum resource could be shared equitably with other ITU Region 2 countries. During the conference, NTIA provided four members to the U.S. delegation and two technical support staff members.

*World Radio Conference.* In addition, NTIA continued to lead government agencies in preparations for the two-part 1985 and 1988 World Administrative Radio Conference for space services. In May 1983, the ITU adopted the agenda for the 1985 session of this conference. U.S. proposals to the space conference are due to the ITU in the fall of 1984. NTIA is developing a technical basis for planning for use of the space service spectrum and will present its planning techniques to the ITU's special preparatory meeting for the 1985 Space WARC to be held in June-July 1984. NTIA will provide five members to the delegation and one member to the support staff. Also, NTIA has been developing a computer-based model, the Geostationary Satellite Orbit Analysis Program (GSOAP), for analyzing geostationary orbit and spectrum use and intersystem interference.

*Comsat Corporation.* In cooperation with the Department of State and the Federal Communications Commission, NTIA participates in overseeing the Communications Satellite Corporation's activities in the International Telecommunications Satellite Organization (INTELSAT) and the International Maritime Satellite Organization (INMARSAT). INTELSAT's annual growth in revenues and circuit use continued at a rate of more than 20 percent, its capital ceiling was increased to \$2.3 billion, and orders were placed for five Intelsat VI series communications satellites, which will have about 25 percent greater capacity than the Intelsat V series.

#### *Geodesy*

*Polaris Network.* In 1983, NOAA completed a three-station radio telescope network, designated the Polaris network, with stations in Westford, Massachusetts; Fort Davis, Texas; and Richmond, Florida. This network, using the very-long-baseline-interferometry (VLBI) measurement technique, replaced the optical telescope system operated for 80 years and measures earth rotation and polar motion with a twentyfold improvement in accuracy.

*Global Positioning.* NOAA began using Global Positioning System (GPS) geodetic receivers for precise identification of positions on the surface of the earth. The GPS receivers have proved more accurate and more economical than conventional geodetic tech-

niques. Over the next decade, GPS receivers are expected to become the primary technology used to maintain national geodetic networks.

*Elevation Profiling.* NOAA began a joint project with NASA to demonstrate an ability to make high-accuracy elevation profiles of ice, land, and ocean surfaces when using GPS receivers for navigation and altimeters to determine height difference. Test flights are planned for 1984 with NOAA GPS instrumentation mounted on a NASA P-3 aircraft equipped with both laser and radar altimeters.

#### *Time.*

National Bureau of Standards scientists developed a system to synchronize the rate of clocks at remote locations with an accuracy to less than 10 billionths of a second. Global Positioning System satellites built by the Department of Defense provide navigational data, and NBS scientists developed receivers with a billionth of a second stability in the delay time of the receiver circuit. In addition to comparing remote high-accuracy clocks, the technique has promise for synchronizing the frequencies of Jet Propulsion Laboratory's deep-space tracking stations at Goldstone, California; Madrid; and Canberra, Australia.

## **Space Support Activities**

#### *Software Development*

NBS provides technical assistance to NASA in planning software for the Space Station. Because the Space Station project will demand greater cooperation among the NASA field centers, a new approach will be required for managing software. The Bureau's Institute for Computer Sciences and Technology is a technical consultant helping NASA establish a program of guidance, automated support, training, and information services to support the updated software policies.

#### *Infrared Spectroscopy*

NBS developed a new tunable source for far-infrared spectroscopy that can make significant contributions to atmospheric chemistry, radio astronomy, laser communications, and position location through the atmosphere. Before this development, sufficient power for far-infrared spectroscopy was available only at the fixed frequencies of laser sources. Now the entire range from 500 to 4,000 GHz can be covered by mixing infrared sources on a point-contact device in such a way that the difference frequency is radiated to free space. As much as 0.2 microwatts of tunable, continuous-wave radiated power has been generated.

#### *Space Shuttle Support*

NBS is assisting Rockwell International in developing sensitive, nondestructive devices for inspecting the Space Shuttle's main engine. The discovery of small

cracks in fuel lines focused attention on the need for reliable inspection of subcritical cracks. Inspection is difficult because of the small size of the cracks, the configuration of the fuel tanks, and the nature of the alloys. The joint effort will evaluate a new eddy-current inspection device developed at NBS, which operates at higher frequencies and broader bandwidths than the conventional, commercially available eddy-current probes. The NBS probe may be more sensitive to small cracks in components made of alloys with very high electrical resistance. The design of the NBS probe also makes it more suitable for quantitative work.

At NASA's request NBS is determining whether vortex-shedding flow meters are suitable for use on the Shuttle. The Shuttle's main engines consume large quantities of liquid oxygen and hydrogen while lifting off and accelerating to orbital velocity. The flow rates, which reach 57 meters per second, must be measured accurately to achieve maximum thrust from the engines. Because flow meters with moving parts present a hazard in the liquid oxygen duct, NASA asked whether a vortex-shedding flow meter would be suitable. In feasibility tests, using water for simulation, the flow meter performed satisfactorily at flow rates up to 46 meters per second, establishing the capability of such an instrument to measure high-speed flows. NBS is now modifying existing designs to allow more precise counting of the vortices.

NBS also is studying heat transfer to assist NASA in assessing the feasibility of recovering unexpended liquid oxygen and hydrogen propellant from the Shuttle's main tank after the orbit burn has terminated. Recovery of the remaining propellant would extend the time the Shuttle could remain in orbit. In a related project, NBS has measured the thermal conductivity of liquid hydrogen at very high temperatures, completing a 22-year series of measurements of the thermophysical properties of liquid hydrogen and oxygen for the manned space programs.

#### *Fiber-Reinforced Composites*

NBS is cooperating with NASA's Langley Space Research Center, the University of Illinois, and several manufacturers of composites to develop a way to measure the resistance of composites to crack growth. The use of fiber-reinforced composites in aircraft bodies substantially reduces the overall weight, permitting an increase in fuel or payload. However, the development of cracks in the polymer material binding the fibers is a major concern. Because such cracks may occur in the interior they are difficult to detect; little is known about how to repair them or even how important they are. For this reason it is essential to obtain polymers that resist cracks and to develop test methods to evaluate this resistance.

#### *Spectrometer Calibration for Solar Irradiance Measurements*

Use of the NBS synchrotron ultraviolet light source (SURF-II) to calibrate ultraviolet spectrometers is significantly improving measurements of the solar ultraviolet irradiance. Solar radiation at wavelengths shorter than 298 nanometers is totally absorbed by the earth's atmosphere and provides the dominant source of energy for atmospheric heating, dissociation, and ionization. An accurate knowledge of the irradiance in the ultraviolet is therefore fundamental for studies of the photochemistry of the upper atmosphere. Until recently, the few available measurements have been plagued by major uncertainties. In January 1983 scientists at the University of Colorado measured the full-disk solar ultraviolet irradiance from a rocket flown above White Sands Missile Range. They report that the use of SURF-II to calibrate their spectrometers has substantially reduced the errors in their measurements.

#### *Detector Calibration for Space Telescope*

NBS made absolute calibrations of a group of far-ultraviolet detectors to be used in experiments on NASA's *Space Telescope*, scheduled for launch into orbit in 1986. These digicon detectors will resolve stellar spectra from the high-resolution spectrograph and the faint-object spectrograph, two of the five experiments on the *Space Telescope*. The NBS project provided NASA engineers an important clue to identifying a problem in the optics of one of the spectrographs. The calibration, with a knowledge of the efficiency of the optical systems, will permit precise measurement of the photometric performance of the two spectrographs.

#### *Ozone Concentrations*

In response to a request from the Environmental Protection Agency, NBS designed and constructed a new ultraviolet photometer for calibrating ozone monitors. The new photometer yields the concentration of ozone in a sample by measuring the amount of ultraviolet mercury radiation at 470 nm (254 nm) that it absorbs. Accuracy is limited to about two percent by uncertainty in the value of the ozone absorption cross-section at 470 nm. NBS was completing studies at the end of 1983 of the dependence of ozone absorption on temperature, to improve accuracy of ozone absorption measurements. The new photometer was the standard for calibrating 19 instruments that will fly in the NASA Balloon Ozone Intercomparison Campaign. It will replace the existing NBS standard-ultraviolet-ozone photometer and will serve as a primary standard for EPA laboratories.

## Space and Atmospheric Research

### *Gravitational Waves*

NBS is exploring the feasibility of an experiment to detect gravitational waves in space. The first major objective is to search for gravitational-wave pulses with periods of minutes to a few hours and with fractional strain amplitudes of roughly  $10^{-20}$ . Detection of such pulses would provide a unique capability for studying events associated with very large masses in the universe. Events include current collisions of massive black holes, which may exist at the centers of many galaxies and probably provide the energy source for quasars. They also include collisions of such objects during the earlier history of the universe when galaxies were forming. The second objective is to detect continuously emitted gravitational waves from both known and unknown rotating binary stars. The experiment includes three test masses in orbit about the sun with a separation of  $10^6$  km or more. Variations in the separations would be determined by laser heterodyne measurements.

### *Materials Processing in Space*

NBS is measuring the effects of fluid flow on the solidification of materials. Of particular interest are gravity-driven flows that can arise from differences in temperature or composition and can affect the homogeneity of the solidified material, substantially degrading its performance. In space, gravity-driven flows will be greatly reduced.

### *Meteorology*

*Mesoscale and Severe Storms.* In support of NOAA research, the University of Chicago continued investigating the behavior, identity, and dynamics of severe thunderstorms, particularly those producing tornadoes and destructive downbursts. One study determined that the crash of PanAm flight 759 in New Orleans on July 9, 1982, was due to a microburst, a small but intense downdraft of air. The FAA concurred in this conclusion. A microburst can generate a powerful radial outflow of air at or near the surface, causing aircraft passing through it to experience sudden winds that dangerously alter lift or flying ability. Many storm systems are identified in satellite and radar imagery as potential hazards, but many are indistinguishable because of their small size and shallow vertical development. For the air traffic problems, the university investigator recommended a study to test the ability of Doppler radar to detect and give sufficient warning of microbursts at or near air terminals.

*Improved Forecasts.* NOAA's Prototype for Regional Observing and Forecasting System (PROFS) is developing and testing techniques to combine data

from satellite, radar, and surface meteorological networks, plus ground-based atmospheric soundings to produce improved, short-term (0- to 12-hour), local-scale forecasts. Initial applications emphasize warnings of severe storms and flash floods.

NOAA's weather research program used its satellite rain-estimating technique for the summer 1983 PROFS experiment. The unique capability is a first step toward testing and ultimately using satellite rain estimates for regional forecasting. Rain estimates for tropical storms and hurricanes in the Atlantic Ocean were made from the PROFS data base during this year's hurricane season to support the pilot project of a joint NOAA-NASA aircraft program.

*Wind Sensing.* Under contract to NOAA's Wave Propagation laboratory, RCA Astro-Electronics showed that it is feasible to carry an infrared Doppler lidar for global wind sensing on an Advanced Tiros-N spacecraft. This *Windsat Free-Flyer* would be able to measure wind at 10 to 15 levels in the atmosphere at an accuracy within a few meters per second.

*Radiation Budget.* A complete and extensive set of satellite observations was carried out to measure the planetary radiation budget. Both wide field-of-view and narrow field-of-view *Nimbus 7* data were processed and analyzed for November 1978 through October 1979. Comparisons between the two fields show excellent agreement in their spatial and temporal variability. Also developed for the *Nimbus 7* earth radiation budget experiment (ERBE) were angular reflection and emission models and models depicting the dependency of albedo on solar zenith angle. The models also will be used to estimate radiation budget parameters obtained from the AVHRR aboard NOAA operational spacecraft.

Processing of AVHRR data from the NOAA Tiros-N satellites continued. Almost nine years of data—about four years from pre-Tiros-N satellites and almost five from the Tiros-N series—have been processed. The estimates of emitted flux indicate that despite different equator-crossing times the daily average values are reasonably consistent, permitting construction of a climatic data base for diagnosing year-to-year anomalies.

*Cloud Studies.* An improved algorithm was developed for estimating low, middle, and high cloud from *Nimbus 7* observations. The new approach supplements the 11- and 6.7-micrometer data from the temperature-humidity infrared radiometer (THIR) with concurrent surface temperature and with reflectance measurements from the total-ozone-mapping spectrometer (TOMS). This additional information improves definition of the cloud or no-cloud thresholds, greatly improving estimates of cloud cover. A four-year cloud data set from April 1979 through March 1983 will be produced.

## Solar Activity

*Sun Charts.* Observations of activity on the sun were processed into newly developed charts, much like those depicting weather patterns over the earth's surface. Current charts serve the NOAA Space Environment Laboratory's solar-terrestrial forecast warning service. A catalog of historical charts was compiled for the past two solar cycles (22 years). These provide better definitions of the solar surface activity and establish boundary conditions for magnetohydrodynamic (MHD) computer models of the propagation of the effects of solar disturbance through the interplanetary medium to the earth. Development and testing of full three-dimensional models began, and predictions of geophysical disturbances obtained from extended two-dimensional models are being tested against observations.

*Geomagnetic Field.* An innovative mathematical technique was developed to analyze observations of the geomagnetic field by a North American Network of magnetometers. The technique promises to enhance the ability to infer the characteristics of ionospheric currents and of their responses to solar-induced, interplanetary disturbances that cause geomagnetic storms.

*Sun Energy.* A statistical model of the total power delivered to the polar atmosphere was developed by analyzing energetic-particle-detector data from *Tiros-N* in 1978 through the present *NOAA 7* and *8* spacecraft. Data from each satellite pass over the polar regions were used to infer the immediate global solar energy contribution of importance to the electrical properties and the meteorology of the ionosphere and upper atmosphere.

## Aeronautical Programs

### Flyway Charts

NOAA, which produces aeronautical charts and chart-related products for navigation in U.S. air space, announced that effective August 4, 1983, Visual-Flight-Rules Flyway Planning Charts would be printed on the back of the existing Los Angeles and San Diego VFR Terminal Area Charts (TAC). Previously, TAC charts were printed back-to-back. VFR Flyway Planning Charts are designed to assist pilots in planning their flights through or around areas of high-density aircraft operations. The Federal Aviation Administration will solicit aviation user groups to determine product acceptability. If the response is positive, additional VFR flyways will be considered for congested terminal areas.

### Aeronautical Research

NOAA continued to study weather hazards for aviation and Space Shuttle flights. Turbulence, wind shear, gust fronts, downbursts, and lightning location and characteristics are investigated with a network of weather radars, dual-Doppler weather radars, automated surface observations, rawinsondes, a 44-meter meteorologically instrumented tower, and satellite and aircraft observations. Identification of these phenomena for warnings and investigation of precursors that may be used in forecasting hazards are included in joint cooperative projects with NASA, FAA, and DoD. In conjunction with the multiagency Next-Generation Radar (NEXRAD) Joint Systems Program Office (JSPO), techniques for data acquisition, processing, and display of aviation weather hazards are being investigated along with the development of criteria for effective placement of Doppler weather radars to service aviation and public interests.



# Department of Energy

The Department of Energy (DOE) and its predecessor agencies have performed specialized research and development in support of the military and civilian space programs since the early 1960s. Nuclear sources of electrical power for space applications have been key elements of some of the more ambitious U.S. astronautical undertakings. Compact size, light weight, and long life are the unique characteristics of the nuclear power systems that enable spacecraft, satellites, and other remotely located devices to operate without external sources of energy for long periods of time. Nuclear systems have provided the self-sufficiency that has made possible many of the space missions of NASA and the Department of Defense.

## Space and Special Applications of Nuclear Power

Research and development in the Space and Special Applications Program provide safe, compact, and environmentally acceptable energy systems to federal agencies for earth-orbital and interplanetary space missions, as well as for other special-purpose applications. The program in 1983 consisted of three major projects: (1) the static outer-planetary radioisotope thermoelectric generator (RTG) projects, developing RTGs for NASA's *Galileo* spacecraft to be launched to Jupiter in 1986 and the International Solar Polar Mission (*ISPM*) spacecraft to be launched in 1986 to study the sun; (2) the space reactor technology program (SP-100), an advanced technology readiness program; and (3) a terrestrial RTG project.

### *Radioisotope Thermoelectric Generators.*

Since 1961, the United States has used 34 RTGs developed by DOE and its predecessors as electrical power supplies in 19 space systems, including navigation and communication satellites launched by DoD and the Nimbus, Apollo, Pioneer, Viking, and Voyager spacecraft launched by NASA. These RTGs have encompassed six design concepts spanning beginning-of-mission power ranges from 2.7 to 159.2 watts of electricity. RTGs have proved to be reliable, long-lived sources of electrical power. Most of them, from the SNAP-3A to the multihundred-watt RTG

(MHW-RTG), have exceeded their mission requirements by providing power at or above the levels required and for longer than the planned lifetimes of the missions.

The general technological objective of each RTG design has been to improve generator performance, efficiency, and specific power. This has led to improvements in the technology of thermoelectric materials, from the lead telluride (PbTe) used in the first five RTG designs to the silicon germanium (SiGe) used in the MHW-RTG and the RTGs being built for future space missions. The performance of these generators has demonstrated that nuclear power sources can be safely and reliably engineered to meet a variety of space mission requirements.

In 1983, research and development included fabrication of thermoelectric converters for qualification and flight-unit general-purpose heat-source (GPHS) RTGs to be used in an advanced silicon-germanium generator for *ISPM* and *Galileo*. The 55.5-kilogram GPHS RTG is designed to provide a versatile, modular, plutonium-238 fuel unit suitable for numerous space applications. It offers a minimum of 285 watts of electricity, with a fuel loading of 4,410 thermal watts. During 1983, thermal and dynamic testing of the engineering unit was completed, and life testing was begun. The RTG Assembly and Testing Facility was completed. Production, component fabrication, and tests of the *Galileo* radioisotopic heater units also were completed. The isotope-fueled modules were assembled, and loading into thermoelectric converters will begin in 1984. The fueled power units will be tested at qualification and flight acceptance levels. Fueling and testing of the qualification converter will begin in early 1984; fueling and testing of the flight converter are planned for later in 1984.

### *Advances in Supporting Technology*

Development of a new RTG concept, the modular isotopic thermoelectric generator (MITG), made significant progress. The MITG offers the potential for a more advanced, much lighter generator for future space missions. The basic design will be adaptable for many space uses, since the power output can be scaled in 20-watt increments by varying the number of generator slices (identical sections of the standard design), usually without other design changes. Any in-

intermediate power level can be provided by minor modification of the radiator fin dimensions. In the earlier multihundred-watt isotopic generator, changing the power level required major redesign and requalification of the heat source. Even in the GPHS generator, which uses the same modular heat sources as the MITG, changing the power level would usually require major changes in the thermoelectric couples and circuit.

The MITG promises substantially higher specific power than provided by the present RTGs, with no reduction in safety and with increased reliability. It permits performance checking of individual thermoelectric modules in the assembled converter and replacement of any deficient ones. It should also be more economical, because of its modularity, scalability, and flexibility.

During 1983, DOE completed fabrication and began performance-testing eight MITG test modules. The test data will help determine further development of this new concept. Design of a ground demonstration system using the MITG approach began in 1983, and program plans call for fabrication of thermoelectric modules for testing in 1984, fabrication of the ground demonstration system in 1985, and testing in 1986.

### *Space Reactor Technology*

Space nuclear-reactor systems can provide high levels of electrical power—usually 25 kilowatts or more—for a variety of applications in space. In early 1983, the Los Alamos National Laboratory continued development of critical components for a specific reactor power system using heat pipes for its heat transport and radiator subsystems.

In February the Defense Advanced Research Projects Agency (DARPA), NASA and DOE signed a memorandum of agreement on developing technology for space nuclear-reactor power systems. The resulting SP-100 program will support both civilian and military space applications. The three agencies established a management organization to meet the immediate objective of assessing whether present technology is sufficient to permit a commitment in mid-1985 to proceed to a ground-engineering test phase beginning in 1986. A technology assessment and advancement phase (phase I) began in May 1983 to

- Evaluate the ability of the nuclear-reactor heat-source and power-conversion concepts to meet certain performance requirements, leading to the selection of baseline, backup, and growth designs;
- Initiate a number of key technology and safety development tasks;
- Analyze mission requirements to determine whether they can be met by nuclear power and to assess how reactors can be employed for specific applications.

Four major contractors evaluated several conceptual designs during 1983, and one or more will be selected

in early 1984 to continue with their proposed designs. Technology suitability and performance were investigated in a number of areas: nuclear fuels, refractory alloys, and other materials for high-temperature applications; heat pipe, liquid metal, thermoelectric, and thermionic conversion; nuclear safety aspects; and nuclear radiation and shielding. These activities will continue in 1984. Mission analyses and requirement studies began in 1983, and DoD and NASA review groups were established to examine the requirements identified. These activities will also continue in 1984. Success in these three activities—system design, technology development, and mission analysis—will determine whether the SP-100 program proceeds into its ground-test phase (1986-1989) and flight-qualification phase (1990-1993).

A related effort, the development of a multi-megawatt space power reactor (as opposed to the smaller 100-kilowatt level of SP-100), proceeded in parallel but at a much lower level of effort, as part of the SP-100 program. This effort may be expanded in 1984 in response to the needs of several potential civilian and military missions, in particular the proposal to develop a space defense against ballistic missiles.

### **Remote Sensing of the Earth**

Satellites carrying instruments that monitor the earth's surface and atmosphere continued to provide useful data for geological and environmental research applications. For example, remote-land-sensing systems were being used in development of exploration technology for natural resources, in research conducted for DoD by the national laboratories and in other research operations.

### **Nuclear Test Detection**

DOE supports the national nuclear-test-detection mission by supplying spaceborne nuclear detector systems used in monitoring tests to ensure adherence to the nuclear test-ban treaty. Optical and radiation detectors are flown as secondary payloads on DoD and NASA systems. The mix of satellite systems, when fully deployed, will permit worldwide surveillance for nuclear testing, both inside and outside the earth's atmosphere.

The national laboratories are responsible for designing, fabricating, and testing detector packages, which consist of sensing elements, their electronic circuitry, and the downlink telemetry logic. A DOE research and development program seeks to upgrade radiation hardening and increase sensitivity and coverage, to improve data processing and reporting, and to provide a means of distinguishing background signals from nuclear events in order to prevent false alarms. During 1983, DOE delivered a number of detection systems, including the most complex piece of equipment yet developed by DOE for space monitoring.

# Department of the Interior

As principal steward of the nation's natural resources, the Department of the Interior administers more than 2 million square kilometers of federal land and has trust responsibilities for an additional 200,000 sq km of Indian reservations and island territories. The department promotes the wise use of public land, mineral, and water resources; protects the nation's fish and wildlife; preserves the national parks and historical sites; and provides services for Indians and for native peoples of Alaska. Management and monitoring for such diverse responsibilities over vast areas are facilitated by data acquired by sensing systems on aircraft and satellites. Capabilities are enhanced by research and advancement in spatial data-handling technology.

Bureau and agencies of the Department of the Interior participating in remote-sensing studies during 1983 included the Bureau of Land Management, Bureau of Reclamation, National Park Service, Bureau of Indian Affairs, Office of Surface Mining Reclamation and Enforcement, and the Water Resources, Geologic, and National Mapping Divisions of the U.S. Geological Survey (USGS).

## Earth Resources Observation Systems

During 1983, the Geological Survey's EROS Data Center (EDC) near Sioux Falls, South Dakota, assumed direction of the EROS interbureau mission for developing and demonstrating applications of remotely sensed and other digital data sets for earth science. This responsibility had previously been shared with a headquarters office in Reston, Virginia, which was closed as part of an administrative realignment within the National Mapping Division of USGS. EDC cooperates with divisions of USGS and other Department of the Interior bureaus to develop and test methodologies for supporting department responsibilities. EDC also conducts research in hardware and software development for merging and manipulating disparate kinds of digital data and for digital image processing.

EROS has represented the department on the Source Evaluation Board for Civil Space Remote Sensing. This board is developing, under direction from the Secretary of Commerce, a request for proposals to transfer the operational civil weather satellites (geosta-

tionary and polar) and land (Landsat) remote-sensing satellites to the private sector. Issues of particular concern include continuity of data, nondiscriminatory and open dissemination of data to all users, and maintenance of archives so that data will continue to be available for departmental programs.

## *Digital Data-Base Development and Applications*

The USGS National Mapping and Geologic Divisions completed a pilot project on the Medford, Oregon, quadrangle for the Federal Mineral Lands Information System. The project demonstrated the concept of an operational system synthesizing information on federal surface and subsurface ownership, mining restrictions, mineral assessment, etc., into a computerized spatial-data base and analyzing the data to help formulate national policy governing mineral use. Products of the investigation include the digital data base, large-format prints, 35-mm slides, and a report on potentials and limitations of a digital approach for national-level data bases.

The Geological Division, EROS Data Center, and Missouri Geological Survey cooperated in research to develop and test a digital geologic-data base for mineral resource assessment of the Rolla, Missouri, quadrangle. The data base consists of 20 numerically encoded layers of surface and subsurface geological, geochemical, and geophysical data that were digitized from 1:250,000-scale maps. Two additive numerical models were applied to the data base to identify and rank areas considered to have a significant potential for lead and zinc resources.

Using U.S. GeoData (digital USGS data) and Landsat digital data in a digital spatial data base, the EROS Data Center, Bureau of Land Management, and the Soil Conservation Service generated soil survey maps for five quadrangle areas in Idaho and Wyoming. Slope class maps from the digital terrain data and topographic maps, used with orthophoto-quadrangles, produced preliminary maps employed in the field to complete the soil mapping process. Digital data make it possible to list terrain, spectral, and other information from the data base for each mapping unit. A two-year field evaluation has proved that these products are accurate and reliable for soil mapping. In addition to saving time during the field work, the maps are valuable for updating old surveys, quality control, correlation

efforts, and soil interpretations. They also provide an effective tool for land management in areas where detailed soil surveys are not yet complete.

The EROS Data Center and the Bureau of Indian Affairs developed a geographic information system for resource management on the Ft. Berthold Indian Reservation, North Dakota. Geographically registered map data from published government reports and surveys, digital terrain data, digital line graphs, and Landsat data were analyzed by computer to produce map and text data for resource management. Products include reservation-wide management-opportunity maps and corresponding tabular data. An automated procedure was developed to determine rangeland base premiums for Indian trust land according to production potential.

In a proof-of-concept test for a national water resources summary, EROS cooperated with the USGS Water Resources Division to register 50 data sets from digitized maps and digital data files for the Fox-Wolf River basin of east-central Wisconsin. The merged sets were used to describe quantity, quality, and problems of the water resources. This computer processing offers an objective method of showing facts and relationships, in readily understandable maplike forms.

The EROS Field Office in Anchorage, Alaska, and the Water Resources Division are developing a digital data base containing the geographic location, an index number, acreage, and other attributes, such as water quality, for lakes greater than five acres on the North Slope of Alaska. The basic data are water classes derived from a digital land-cover classification of Landsat data covering the National Petroleum Reserve, Alaska. The data base was completed for nine quadrangles within the reserve and work began on six additional quads on the North Slope. It will be used by the Bureau of Land Management in its on-shore oil and gas assessment and leasing program.

#### *Data Handling*

The EROS Data Center operated the final data processing, data archives, and product generation and distribution portions of the Landsat ground segment for the National Oceanic and Atmospheric Administration (NOAA) during 1983. Data Center computer and photographic processing systems were modified to handle new formats for the *Landsat 4* multispectral scanner (MSS) data and data from the new thematic mapper (TM) sensor. EROS added some 18,000 MSS and 300 TM images to the existing *Landsat 1*, *2*, and *3* archive of almost 600,000 scenes.

As part of the USGS side-looking airborne radar (SLAR) program, a contract was awarded to Intera Environmental Consultants Inc., of Houston to acquire some 610,000 sq km of aerial SLAR coverage in the eastern United States. The data will be acquired and entered into the public domain in 1984. The program, begun in 1980, has acquired partial or complete

radar image data for 22 states, including Alaska. The data are expected to aid both private-sector and government scientists in energy-resource and mineral research projects in the use of these data for cartographic and hydrologic applications. In addition, the Geological Survey has supported more than 50 geologic applications.

#### *Remote Information Processing*

The second phase of the remote information-processing system (RIPS) began with the procurement of 18 commercially built RIPS units based on an EROS Data Center prototype. Eleven units were installed at sites of the five government agencies that joined in this procurement. Employees at the agencies began operational use of RIPS, designed to extend the use of Landsat and other remotely sensed data to users in the field. A RIPS task team is completing baseline software to support traditional image processing, which includes basic map-overlay analysis and color graphics. The software allows access to the EROS computer network for ordering data products and custom image-processing. EROS also provides Landsat digital data on floppy disks for 7.5-minute map quadrangle areas.

### **Monitoring the Environment**

#### *Land Cover Inventories*

The EROS Field Office in Anchorage has cooperated during the past three years with state and federal resource management agencies in Alaska to classify vegetation and land cover for comprehensive planning, research, and management mandates of the Alaska National Interest Lands Conservation Act of 1980 and for inventory requirements of the Forest and Rangeland Renewable Resource Planning Act of 1974. The vegetation and land-cover classifications were derived from Landsat computer-compatible tapes using standard digital-image-processing techniques, and a standardized classification map is being produced for Alaska. To date, some 600,000 sq km have been classified through digital processing of Landsat data and merging with digital terrain data. These data are used primarily for estimating land-cover acreage and for producing habitat-suitability models for various wildlife species.

The Bureau of Reclamation uses aerial photographs in several land-inventory and wildlife-habitat-assessment investigations. The impact on croplands and wildlife of construction associated with the Grand Valley Salinity Control Project in western Colorado is monitored by comparison of preconstruction and postconstruction aerial photographs. Early morning aerial photographs to inventory roosting sandhill cranes in Nebraska, coupled with river transect measurements, enabled biologists to monitor roosting

habitat preferences. Overexposed color-infrared aerial photographs are being used to map submersed aquatic vegetation on national wildlife refuges along the James River in North Dakota. Similarly, aerial photographs have been used to map wetland habitat along the proposed right-of-way for the New Rockford Canal. A methodology for monitoring noxious weeds is being developed by analyzing aerial photos of areas in Montana to determine at what scale and time of year the weeds are most easily detected.

#### *Cultural Resources Inventories*

The National Park Service, Southwest Region, used large-scale aerial photographs (1:3,000) to support inventory and evaluation of the archeological resources of the Chaco Culture National Historical Park in the southwestern United States. Direct plotting of archeological sites by visual comparison with the aerial photos provides a faster, more accurate method of recording the sites, more usable description of the physical environment, and reduced requirement for collection of field data.

#### *Forest Fuel Mapping and Fire Control*

Bureau of Land Management fire managers require a low-cost, effective means of mapping fire fuels for thousands of square kilometers of public lands. The Bureau, EROS Data Center, and NOAA jointly evaluated the use of data from the NOAA's satellite-borne, advanced very-high-resolution radiometer (AVHRR) for mapping wildland fire fuels over 170,000 sq km in eastern Oregon. They developed a geographically referenced data base containing terrain information, road network, ownership, and AVHRR data acquired during April, May, and June to produce a map of wildland fire fuels at a cost of 25 cents per square mile (2.6 sq km). The final fuel information was portrayed as a 1:250,000-scale map that is being used by fire management officers to help predict ignition probabilities, fire intensities, and rates of spread. An additional 368,000 sq km were mapped in Montana, Colorado, and Arizona.

The National Park Service also is using 1:250,000-scale digital terrain tapes and Landsat TM data for mapping vegetation and modeling fire fuels in Alaska.

#### *Water Resource Analysis*

The Bureau of Reclamation developed a technique for atmospheric correction of Landsat data to permit estimating the state of nutrition in reservoir waters from remotely sensed images without concurrently gathered surface-truth data. It was successfully demonstrated with the processing of scenes of Flaming Gorge Reservoir from 1976, 1977, and 1978, during which time the reservoir had not been sampled. The bureaus also used aerial photographs to find sources of saline

water within the drainage basin of the Dirty Devil River in Utah under the Colorado River Salinity Control Act.

Side-looking airborne radar images of a portion of New Jersey are being studied to determine if fractures in the outcrop area of the Woodbury clay can be mapped. This cooperative project of USGS and the New Jersey Geological Survey is designed to detect areas where fractures in the clay bed may limit or prevent its use for waste disposal.

#### *Irrigation Analysis*

A digital image-processing system was being installed in 1983 in the USGS Denver laboratories for mapping crops periodically on the High Plains in an eight-state area. The crop maps are used to select specific sites where the amount of ground-water pumped out is measured during the irrigation season. Pumpage is correlated with the drawdown of water from the Ogallala aquifer and requires continued monitoring to determine the benefits or adverse effects of the ground-water use.

The Water Resources Division is using Landsat images to map crops during the irrigation season in the lower Colorado River Valley to aid in determining the amount of water diverted for irrigation, used by the crops, and returned to the river. The repetitive Landsat coverage is more cost-effective than repeatedly acquiring aerial photographs for the same purpose.

The Bureau of Reclamation and the state of Wyoming are applying remote-sensing techniques to assessing the beneficial use of water in the 39,000-sq-km Upper Green River basin. Data from satellite images and aerial photographs are statistically linked to provide irrigated area estimates. Estimates of reservoir surface areas assist in computation of evaporation losses. An investigation also is comparing the capabilities of three digital image sets—Landsat MSS data, thematic mapper simulator data, and airborne MSS data—for inventorying irrigated agriculture near Delta, Utah. A computer-enhanced Landsat MSS image of geologic structures aided the Wyoming Water Development Commission in choosing a site for a deep well for irrigation east of Greybull, Wyoming.

#### *Weather Monitoring*

The Bureau of Reclamation uses a Geostationary Operational Environmental Satellite (GOES), managed and operated by NOAA, as a source of real-time cloud images for all Division of Atmospheric Resources research field projects, and digital satellite data are used for the Sierra Cooperative Pilot Project. The data aid in forecasting experimental events, controlling activities, and analyzing results. Specific analyses include identification of cloud types, time histories of cloud systems, and studies of potential downwind effects from cloud seeding. The analyses



will contribute to understanding winter orographic storm systems.

The bureau is continuing its data collection using portable meteorological monitoring or PROBE (portable remote observation of environment) stations. Each station is solar powered and measures wind speed and direction, temperature, relative humidity, barometric pressure, precipitation, and battery status. The measurements are transmitted hourly to a geostationary satellite, which relays the data to a ground station in Denver. The ground station can receive and record data from up to 240 stations per hour and disseminate the data to project scientists as weather developments occur. The Bureau of Land Management has begun to use the GOES satellite to relay data collected from remote automatic weather stations (RAWS) to its ground station at the Boise Interagency Fire Center, Boise, Idaho.

#### *Mine Development and Safety Monitoring*

Large-scale aerial photographs of active surface coal mine areas in the Appalachian and Midwest coal basins are used by the Office of Surface Mining in inspection and enforcement, to detect, inventory, and monitor active areas. A manual for interpretation of low-altitude aerial photographs of surface mining operations was completed to aid the mine inspection. Aerial coverage of alluvial valley floor areas in the western U.S. coal states also supports review of mine plans and examination of the impact of mining on an entire watershed. Thermal-infrared scanner images aid in mapping underground mine fires.

Landsat data help the Bureau of Land Management monitor for possible unauthorized removals of federally owned mineral resources in Arkansas, Missouri, Illinois, and Ohio.

## **Geology**

#### *Geologic Hazards*

Aerial photographs aided the compilation of a report on volcanic hazards to Bureau of Reclamation dams in the Cascade Range of Oregon and California. Aerial photographs also helped find potential geologic hazards, including faults and landslides, at nine dam sites scattered throughout the western United States. Aerial thermal-infrared-scanner images of two dam sites were analyzed to try to locate paths of water seepage from the reservoirs.

#### *Glaciological and Geological Studies of Antarctica*

The Satellite Glaciology Project of USGS used remotely sensed data to support a variety of glaciological and geological investigations in Antarctica. Because the Landsat image contains the precise time of acquisition, time-lapse measurements have

been made of the dynamics of the coast of Antarctica.

Landsat images of the Amery Ice Shelf and terminus of the Lambert Glacier were made into a mosaic as a 1:500,000-scale base for compilation of 1- and 5-meter contours derived from 45 traverses by the *Seasat* satellite's radar altimeter. The experiment reconfirmed the usefulness of satellite image mosaics and maps as the compilation base for various geological, glaciological, and geophysical data. Preliminary research with the British Antarctic Survey established that Landsat images of Antarctica can be used to prepare 1:1,000,000-scale planimetric maps of coastal areas, bedrock exposures, and blue-ice areas.

#### *Space Shuttle Radar Imaging*

During the second flight of the Space Shuttle Columbia in November 1981, 24-centimeter-wavelength electromagnetic signals from the Shuttle imaging radar experiment (SIR-A) penetrated the extremely dry sand sheets, dunes, and drift sand of the eastern Sahara in Egypt and the Sudan to reveal previously unknown buried valleys, geologic structures, and probable Stone Age occupation sites.

Under the sponsorship of NASA, the USGS Geologic Division and the Egyptian Geological Survey and Mining Authority conducted ground reconnaissance of parts of the SIR-A swath in Egypt. Many test pits were dug in the eolian veneer along the radar-detected valleys, and alluvium was found in most of the pits at depths of a few centimeters to 0.3 meter. At one site artifacts were discovered from all three of the known episodes of human occupation.

The ability to map ancient, sand-buried drainage patterns—and, by inference, potential sources of near-surface ground water and possible placer deposits—offers earth scientists a new means of exploring the resources of the earth's hyperarid regions. Because the electrical properties of the extremely dry Sahara sands approach those of the average surface on Mars, the results of the SIR-A mission have generated interest in the potential use of imaging radar for further studies of Mar's geologic history.

## **Cartography**

#### *Landsat 4*

The EROS Data Center investigated the effect of the combined attributes of finer spatial resolution (28.5 meters versus 59) and greater spectral sensitivity (seven bands versus four) for TM data versus MSS data acquired from *Landsat 4*. TM data provided four channels of unique information for resource management, in contrast to two in the MSS data. The improved spatial resolution of TM data aided in locating roads, small stock ponds, and many other land features, permitting positive identification of land-

marks. It also permitted more efficient manual interpretations of land use, better identification of resources, and improved assessment of ecological status of natural vegetation.

Improved spectral resolution of TM data provided a new source of information for natural-resource assessment. TM band 5 and band 7 aided in defining water resources, wetland vegetation resources, and other important terrain features. The added information was useful for both manual interpretation and digital data classification of vegetation and land features. If TM products become available regularly, they will have a high potential for reducing field work needed to monitor rangeland vegetation and land conditions.

### *Image Mapping*

The National Mapping Division continued its research into conversion of Landsat data into image maps. During the year several experimental maps were produced—all based on different kinds of data and meeting national map accuracy standards for the most part:

- Las Vegas 1:250,000-scale satellite image map (color), covering a standard 1° by 2° quadrangle from a digital mosaic of four *Landsat 3* MSS images. The conventional map and the image map were printed back to back.
- Dyersburg 1:100,000-scale satellite image map (color), covering a standard 30- by 60-minute quadrangle and produced from one *Landsat 4* TM image. It was also published in dual form with the line map.
- New Bedford 1:100,000-scale, return-beam-vidicon (RBV) satellite image map of the Cape Cod area, covering an area 30 by 67 minutes.
- Alaska—Several 1:250,000-scale quadrangles of the North Slope area were published with various treatments of MSS and RBV data.
- Foreign areas—USGS cooperated with other U.S. and foreign agencies to produce Landsat image maps of portions of Morocco, Tunisia, Saudi Arabia, and Kenya.

### *Index Maps*

Twenty-six Landsat index maps covering the world at the scale of 1:10,000,000 were jointly published by

USGS and NOAA. The maps indicate the Landsat path and row system for *Landsat 1*, 2, 3, and 4 (and 5 when flown). The maps also summarize the U.S. (EROS Data Center) holdings of *Landsat 1*, 2, and 3 global coverage.

### *Aerial Profiling of Terrain System*

The aerial profiling of terrain system (APTS), under development since 1974, will be a precision, airborne, surveying system that can measure elevation profiles across various terrains from a light aircraft at flight heights up to 1,000 meters above the ground. Fabrication, integration, and extensive laboratory testing of the components (navigation, tracker, profiler, and video subsystems) have been completed at the Charles Stark Draper Laboratory in Cambridge. The components have been installed in a Twin Otter aircraft based at Hanscom Field, Massachusetts. Both ground and flight tests will determine system accuracies and identify and correct any remaining problems.

## **International Activities**

### *Workshops*

During 1983, two five-week remote-sensing workshops for a total of 22 scientists from 12 countries were held at the EROS Data Center. Twenty-one workshops over the last 10 years have trained more than 400 participants from more than 70 countries. Subjects included basic considerations of remote sensing, sources of data, information extraction techniques, and applications for resource management and planning.

### *International Cooperation in Fuels Exploration*

The EROS Data Center and the People's Republic of China's Scientific Research Institute for Petroleum Exploration and Development completed a cooperative investigation of applications of remote sensing to petroleum exploration. Geologic characteristics of the Qaidam Basin in China and the Uinta Basin in the United States were interpreted. Digital geologic data bases were developed, and digital techniques for processing image and ancillary data were tested.

# Department of Agriculture

During 1983, the U.S. Department of Agriculture (USDA) continued development of aerospace remotely sensed data as a source of information for research and operational programs and took steps to enhance the use of data from civil weather and land-observing satellite systems in present global crop-monitoring activities.

By the end of 1983, the midpoint of the AgRISTARS (Agricultural and Resources Inventory Surveys through Aerospace Remote Sensing) program, several significant milestones had been reached. AgRISTARS—a multiyear, multiagency research program to test applications of aerospace remote-sensing technology to agriculture and renewable resources—continued to focus on priority information requirements, notably those related to monitoring crop conditions and improving crop acreage and land-use statistics. AgRISTARS is the focal point for space-related remote-sensing research within USDA, and includes research activities in the Statistical Reporting Service, the Agricultural Research Service, and the Soil Conservation Service, as well as other member agencies of the department. In a continuing effort to achieve greater efficiency, the organizational structure of AgRISTARS was reviewed again and modified to assign individual research agencies in USDA specific research topics. The AgRISTARS Program Management Group will coordinate the individual tasks and projects.

Significant technical achievements in the AgRISTARS program in calendar 1983 included development of processing and analysis capabilities for thematic mapper (TM) data from the *Landsat 4* earth resources satellite, which has been circling the earth since July 1982. The TM, a new, experimental sensor, produces data that have much higher resolution than the data from the Landsat's multispectral scanner (MSS). Evaluation and assessment of advantages to be derived from the higher-resolution TM data is proceeding. Landsat MSS data were a basic source of information for a land-use and land-cover classification system prepared for Missouri, and gridded data bases were developed for the central United States. The data bases—which contain soil information, crop statistics, meteorological data, vegetative index numbers, and related data in crop stress and soil moisture—will facilitate present research and will provide a framework for later operational assessment of crop

conditions, crop acreage, and delineation of areas where major changes are taking place. Of particular note is AgRISTARS's use of Landsat data in making and improving acreage estimates for major crops in seven states.

Analysis of data from meteorological satellites intensified in an effort to explore alternatives to Landsat data. In particular, data from the advanced very-high-resolution radiometer (AVHRR), a sensor on the polar-orbiting meteorological satellites in the National Oceanic and Atmospheric Administration's NOAA series, are being scrutinized in an attempt to extend the use of meteorological satellites in observations of the earth. A significant achievement of the AgRISTARS program was the holding of a "technical interchange" for topics on the AVHRR in June 1983. This special workshop brought together researchers from USDA, the academic research community, and other federal members of AgRISTARS—NOAA, of the Department of Commerce, and the National Aeronautics and Space Administration—in a productive exchange of information in this relatively new applications area.

Within the AgRISTARS program, an independent evaluation of meteorological satellite products was begun as routine production of these products continued, including global-vegetation-index maps, Northern Hemisphere snow maps, and data on Western Hemisphere insolation. Routine production of daily maximum, minimum, and plant-canopy temperatures based on meteorological satellite data also began during the year.

An important feature of AgRISTARS is research toward a better understanding of basic environmental factors that influence plant growth and that must be considered in the development of sensing systems. Soil moisture is one of the basic determinants of plant growth, and AgRISTARS research included an experiment using an aircraft-mounted microwave sensor to determine soil moisture conditions over a Minnesota watershed. Studies of the influence of weather on crop yields continued, and models of weather and crop growth relationships were developed, tested, and evaluated.

To achieve greater efficiency in using aerospace remotely sensed data to monitor global crop conditions, the Foreign Agricultural Service (FAS) moved

its Foreign Crop Condition Assessment Division from NASA's Johnson Space Center (JSC) in Houston to Washington, D.C. The division had been placed at JSC to facilitate the transfer of technology from the NASA center. The move reflects the FAS desire to in-

tegrate more effectively crop assessments derived from Landsat and weather satellite data with information from the other sources, such as attaché reports, foreign government and commodity trade reports, and information from the press and other media.

# Federal Communications Commission

International and domestic satellite communications networks continued to grow and to improve services in 1983 to meet the expanding demand. The International Telecommunications Satellite Organization (INTELSAT) upgraded its 17-satellite global service with launches of the sixth and seventh satellites of the Intelsat V series. Five new U.S. domestic satellites were launched, and orbital spacings between domestic satellites were reduced to permit growth of existing systems and provide for introduction of new systems. The International Maritime Satellite Organization (INMARSAT) requested proposals from industry for additional maritime satellite capability. INMARSAT has a lease agreement with INTELSAT to provide maritime communication service through 1985 using Intelsat V and V-A satellites. Several new specialized satellite systems were proposed for mobile and data-acquisition services, as well as two new commercial systems proposed for international services.

## Communications Satellites

### INTELSAT

The INTELSAT global communications system at the beginning of 1983 consisted of two Intelsat IV satellites, five Intelsat IV-As, and five Intelsat Vs. *Intelsat VF-6* and *VF-7* were launched during 1983, with *VF-7* in October as the first Intelsat satellite launched on a European Space Agency Ariane launch vehicle. During the year, the operational satellites were reconfigured in the operational zones: two IVs, three IV-As, and four Vs in the Atlantic Ocean Region; three Vs in the Indian Ocean Region; and two IV-As and one V in the Pacific Ocean Region. *Intelsat VF-8* was scheduled for early 1984 launch on an Ariane. *Intelsat VF-9* and *V-A F-10* were to be launched in 1984 on NASA Atlas-Centaur launch vehicles.

Four new Communications Satellite Corporation (Comsat) ground stations in the Federated States of Micronesia and two in the Marshall Islands joined the INTELSAT global system via the Pacific Ocean satellites. Comsat's Santa Paula, California, station provides leased television channels to Australia via the Pacific Ocean satellites; and Andover, Maine, and Santa Paula stations were equipped to provide Armed Forces Radio TV services to military personnel sta-

tioned in Indian, Atlantic, and Pacific Ocean regions. Time-division multiple-access digital-speech (TDMA-DSI) modulation was introduced in the Atlantic Ocean Region served by Intelsat V satellites. INTELSAT also approved the use of Standard E and Standard Z antennas for ground stations using satellites for digital business service and domestic services.

### Maritime

The commission on January 20, 1983, completed action to make its rules for ship stations conform to INMARSAT equipment and operational requirements. Environmental specifications for equipment were adopted using an option for "recommended" status; equipment authorization procedures were based on a new verification method; INMARSAT approval methods were adopted; witnessing of procedures was left at the option of the manufacturer; ship-station licensing and dissemination of INMARSAT documentation to U.S. entities were provided for. INMARSAT began to lease services through the *Intelsat VF-5*, *F-6*, and *F-7* satellites in the Atlantic and Indian Ocean regions.

National and international efforts continued toward establishing a future global maritime distress and safety system. The system proposes a distress alerting capability by using emergency-position-indicating radio beacons for both polar and geostationary satellites and using INMARSAT in ship distress positions. The United States participated in a coordinated trial program conducted by the International Radio Consultative Committee to evaluate the effective isotropic radiated power of satellites being developed by countries. The system is planned to be in operation by 1990.

### Domestic Commercial Communications Satellites

The domestic commercial communications satellite network consists of 16 satellite locations with satellites operating in the 4-6 Gigahertz bands and 3 using the 12-14 GHz bands. Two aging 4-6 GHz satellites operate in several of the 4-6 GHz locations, for higher efficiency. *Westar 1*, which was the first U.S. commercial domestic satellite (launched in 1974), was retired and kicked out of orbit after serving nine years. The commission has authorized the launch and assigned or-



bital positions for 19 additional domestic satellites, which will bring the total number in orbit to 38 by 1987.

The commission reduced the orbital separations between domestic satellites in the 12-14 GHz bands from 3° to 2° and adopted 2° as the basic, long-term orbital spacing criterion in the 4-6 GHz bands, instead of the present 4° separation. While it concluded that 2° orbital separation in the 12-14 GHz bands are technically feasible immediately with little cost to users, in the 4-6 GHz bands the costs and difficulties warrant a more cautious approach, combining 3°, 2.5° and 2° spacing. The average orbital spacing of 2.5° provides a transition to uniform 2° separations in the future and permits several years for amortizing and upgrading or replacing existing ground stations for the 4-6 GHz bands before operations begin with 2° spacing. Although 3° spacing in the 4-6 GHz bands would be the most expedient way to satisfy present orbital requirements, the commission concluded that this would be insufficient to meet future demands for orbital positions and would limit expansion. It also concluded that 2° spacing is feasible technically with proper satellite and ground-station design, that operational standards and existing ground-station antennas will probably have to be upgraded or replaced, and that greater coordination will be needed between system operators. Benefits of the additional in-orbit capacity would outweigh the increased costs of these changes. Finally, an improved antenna-performance standard was adopted as a revision of part 25 of its rules, to reduce unwanted transmissions from ground-station antennas into satellites adjacent to intended receiver satellites.

The commission noted that its action on reduced orbital spacing of U.S. domestic satellites does not prevent other Region 2 administrations from implementing their own domestic satellite systems and it reaffirmed its commitment to cooperate fully with other countries in the Western Hemisphere through the frequency coordination procedures of the international radio regulations. The FCC announced an agreement with Canada and Mexico on positioning satellites for the three countries between 100° and 120° west longitude.

New technology for more efficient use of satellites and the frequency spectrum continues to bring economic benefits and improved services to satellite users. In addition to such new techniques as companded (compressing the voice channel for transmission and then expanding the received transmission) frequency-division multiplexed-frequency modulation (CFDM-FM) and companded single sideband (CSSB), the FCC has authorized a digital data transmission service that transmits a low-data-rate spread-spectrum signal (SSS) from 1.2-meter ground-station antennas in the 6 GHz band. In the 12 GHz band, the FCC has authorized the use of domestic satellite transponders to provide satellite-to-home television service to subscribers.

### *Direct Broadcast Satellite Service*

Following a comprehensive inquiry and rulemaking, the commission granted construction permits to eight companies to construct Direct Broadcast Satellites (DBS). Specific frequency and orbital assignments were agreed to at the Region 2 Regional Administrative Radio Conference in 1983 (RARC-83). Following the conference, the FCC outlined further procedures for processing the proposals of the eight companies that have construction permits. It accepted three other applications for filing and invited other new proposals. All proposals will be modified to conform to the Final Acts of the RARC-83 conference or a showing will have to be made that the proposals can be technically and procedurally consistent with the agreement. The FCC intends to use the international plan as the primary basis for domestic use of the DBS service. The technical specifications used for planning at RARC-83 provide significant technical flexibility for system variations that are not inconsistent with them. The FCC expects that U.S. licensees will wish to take full advantage of this flexibility.

### **International Conference Activities**

The United States prepared position papers and proposals for submission to the RARC-83 Conference, held in Geneva from June 13 to July 17, 1983. The satellite plan that evolved from the conference was satisfactory to the U.S. The first eight Direct Broadcast Satellite applicants approved by the FCC can be accommodated, as well as the three that are pending. The United States was assigned 8 orbital positions with 32 channels allotted to each, and the Final Acts of the conference contain sufficient flexibility for a wide variety of system configurations within the U.S. The United States reserved its position on two technical issues: the satellite power incident on a service area and the polarization assigned to channels in a service area. Although not all the U.S. proposals were accepted by the conference, the plan adopted is acceptable and causes little concern to domestic implementation of DBS.

FCC continued to prepare for the first session (July 1985) of the World Administrative Radio Conference (Space WARC). The second session will be held in 1988. The conference will seek to guarantee for all countries equitable access to the geostationary satellite orbit and the frequency bands allocated to space services. FCC released a Third Notice of Inquiry in October 1983, requesting public comment on preparations and the initial views expressed in the notice. The FCC Advisory Committee for Space WARC, bringing the nongovernment participants into the preparations, met in February, June, September, October, and December 1983. The committee developed a number of reports on its charter of work. A final report was submitted December 1983.

## New Specialized Satellite Systems

In late November of 1982, NASA filed a Petition for Rulemaking urging the FCC to begin a proceeding toward establishing a commercial Land-Mobile Satellite Service. The service NASA envisioned would provide mobile telephone service in rural areas, long-range vehicle dispatch functions, data transmission and data collection, vehicle position determination, message distribution (paging), and emergency communications. It would operate on frequencies at 821-825 MHz and 866-870 MHz during the developmental phase and would expand, if necessary, to frequencies at 845-851 MHz and 890-896 MHz in the operational phase. These 800 MHz frequencies are now reserved for the land-mobile service. The public was given an opportunity to comment on NASA's petition until April 1983. NASA was also exploring with the Canadian Department of Communications the possibility of obtaining channel capacity from a planned Canadian-government mobile satellite program under a cooperative arrangement. The channel capacity would be used by NASA for experimental purposes.

Since NASA's petition, the FCC has received several applications from companies seeking developmental authority to construct and operate mobile satellite systems. The Mobile Satellite Corporation applied for a system to provide land-mobile satellite service at 800 MHz and at 1500 MHz (L-band) along with

aeronautical-mobile satellite service at the L-Band; the functions of the land-mobile service would be similar to those envisioned by NASA, while the aeronautical-mobile service would provide air-to-ground telephone service, airline-operation communications, and some air traffic control. The Skylink Corporation applied for a system to provide land-mobile service and thin-route point-to-point service at 800 MHz; the functions would be similar to those envisioned by NASA, with emphasis on data collection from remote sensors and on provision of rural telephone. The Geostar Corporation applied for a satellite system to provide data-acquisition satellite services at 1600-2400 MHz; the functions would include vehicle position and velocity determination for land and air, as well as message distribution. Geostar also petitioned the FCC to make frequency allocations to support this system in the bands 1610-1626.5 MHz, 2485-2500 MHz, and 6425-7075 MHz. As a result of this new U.S. industry interest, NASA and the Canadian Department of Communications have agreed to examine an expanded framework for cooperation that would include both government and appropriate commercial telecommunications carriers in the two countries.

Orion Satellite Company and International Satellite, Inc., filed proposals for new satellite systems for commercial international services. At the end of the year, the executive agencies were evaluating the potential foreign policy implications for INTELSAT of these proposals.

# Department of Transportation

Under the Federal Aviation Act of 1958, as amended, the Federal Aviation Administration (FAA)—the aviation component of the Department of Transportation (DOT)—has the responsibility of both regulating and fostering civil aviation. In discharging this dual mission, FAA promotes aviation safety, controls the national airspace to ensure its safe and efficient use, operates a common system of air navigation and air traffic control for the benefit of civil and military aviation, fosters the development of civil aeronautics at home and abroad, promotes an effective national airport system, regulates airport safety, promotes aviation security, and sees to it that civil air operations are conducted in such a way as to do a minimum of harm to the environment.

FAA conducts a variety of research programs. Research is done for the most part by FAA contractors, but FAA's Technical Center at Atlantic City and its Civil Aeromedical Institute at Oklahoma City also take part, as does DOT's Transportation Systems Center at Cambridge. At the same time, FAA conducts joint research and development with NASA, the Department of Commerce (DOC), and the Department of Defense (DoD) and works with foreign governments from time to time on projects of mutual benefit.

FAA's research programs fall into three principal areas: aviation safety, environmental research, and air navigation and traffic control.

## Aviation Safety

### *Fire Safety Research*

FAA has for some years conducted fire safety research to ensure that airline passengers in crashes they otherwise could survive are not trapped inside the planes by postcrash fires when fuel spewing from ruptured wing tanks ignites to form a fireball engulfing the plane. Research, development, and introduction of new standards and equipment to carry out the 1980 recommendations of the Special Aviation Fire and Explosion Reduction (SAFER) Advisory Committee continued in 1983.

The committee was made up of members from the airlines, aircraft industry, universities, public and private research organizations, and flight and cabin crews and was supported by 150 top technical experts

in various fields of aviation fire safety. Its principal recommendations after two years' study were the development of antimisting kerosene (AMK) to reduce or suppress postcrash fires, the design and use of emergency fuel-shutdown and explosion-suppression devices, the design and procurement of fuel tanks and fuel-tank systems capable of resisting rupture regardless of the deformation or failure of the surrounding aircraft structure, and the use of fire-resistant cabin interior materials, including fire-blocking cushion materials.

In the next two years, evacuation slides and fire extinguishers were improved; new standards were established for flight-attendant seats, aircraft wheels and aircraft tires, life preservers, and child restraint systems. Fire-resistant cabin windows were developed, and more effective breathing devices and smoke venting equipment were introduced. The Air Canada in-flight lavatory fire in June 1983, in which most of the fatalities were from smoke inhalation, gave new impetus to the effort. The year was marked by a number of further fire safety actions, also stemming from the 1980 report: (1) fitting passenger and crew seats with layers of fire-resistant materials; (2) improving emergency light-marking systems to help speed evacuation; and (3) validating an antimisting kerosene technology.

For the fire-blocking layers, which would encapsulate the seats with fire-resistant materials, a notice of proposed rulemaking was issued establishing performance criteria (keyed to the average weight loss of the material after it had been subjected to a high-intensity flame for two minutes). The standard, which would permit airline operators to use a variety of commercially available materials to meet their particular needs, was tentatively to go into effect within three years after the rule became final. On light-marking, FAA was satisfied that smoke from burning cabin materials was likely to be so heavy as to wholly obscure existing overhead emergency lighting and hinder evacuation. Accordingly, FAA issued a notice of proposed rulemaking establishing a standard for "floor proximity, escape path marking," which would let airlines work out systems best suited to individual needs. The standard was to go into effect within two years of its adoption.

In 1970 FAA, working with the British Royal Aircraft Establishment (RAE) and NASA, began ex-

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perimenting with a fuel modifier developed by the British and known as FM-9. When mixed in small amounts with jet kerosene, the modifier, a long-grain polymer, markedly reduced the tendency of fuel to mist and form a fireball when fuel ignited in crash landings. FAA built a wing-spillage facility at its Technical Center and demonstrated that, when ignited, conventional fuel quickly developed into a fireball, while the same kind of fuel modified by FM-9 produced a minimal and easily controlled fire. The agency achieved the same result when it rammed a retired aircraft filled with regular, unmodified fuel into a mound of earth and later drove another plane with FM-9 added to its fuel into the same mound. The first plane burst into flame and was wholly consumed minutes after it hit the mound; there was scarcely any fire in the second plane, even though its fuel tanks burst and its fuel was ignited by burning particles from the crash.

FAA was preparing a striking demonstration of FM-9's effectiveness for 1984. FAA will fill an old, four-engine jet transport with FM-9 modified AMK, and NASA will fly it by remote control into the floor of the Mojave Desert, simulating a survivable crash. The controlled impact will also provide FAA an opportunity to measure the crashworthiness of the aircraft and the effect of crash forces on the human body. The plane's fuselage, wings, and floor will be wired with sensors to collect data on their response to the crash. Dummies also will be wired to measure the force of the impact on human beings. The entire area of aircraft cabin safety is expected to be the subject of proposed rulemaking in 1984.

#### *Aviation Security Research*

FAA's aviation security program again emphasized research in detecting explosives. Long-standing programs developing devices to detect explosives in air cargo, checked baggage, and baggage carried by individual persons continued, and a new program on automatic detection of flammable liquids began. A nationwide explosive-detection conference reviewed the state of the art and examined new developments. FAA pursued four continuing explosive detection programs during 1983, named for the most part for the basic scientific principle on which each is based.

*X-Ray Absorption.* A new device detects explosives by automatic, computer-based analysis of the size, shape, and x-ray density of the baggage checked. Operational evaluation of the device, the first of its kind to be developed anywhere in the world, indicated that it has the potential of meeting FAA requirements for a dependable explosive-detection system. An advanced, adoptive algorithm was designed to enhance its detection capability and reduce false responses. A 90-day operational evaluation of the device at Dulles Interna-

tional Airport revealed its performance to be greatly improved by the new algorithm.

*Thermal-Neutron Activation.* In an advanced system, explosives are detected by identifying the nuclear reaction peculiar to the explosive material present when it is bombarded with thermal neutrons. Test data taken at Pittsburgh and Boston airports showed the system had good possibilities for detecting explosives in air cargo and checked baggage. The research and development contract was modified in 1983 to enhance the detection algorithm of the system and to provide for gathering additional operational data.

*Nuclear Magnetic Resonance.* The basic principle of another device is to capture and display the characteristic response of molecules of explosives when they are subjected to magnetic and pulsed radio frequencies. Analysis of the data obtained with a laboratory model revealed that the concept was feasible experimentally, but test results during a two-week evaluation at Dallas-Fort Worth Regional Airport were disappointing. A scheduled operational evaluation was postponed, and the contract was extended to permit additional research.

*Walk-By Explosives Detector.* FAA has spent a great deal of effort in the recent past trying to develop a device that would routinely detect explosives carried by individual persons, but without success. However, because of recent developments in vapor-collection and sampling technology, DOT's Transportation System Center has been authorized to contract for new private development of explosive detectors suitable for the purpose.

Further, in a departure unlike anything it had tried before, the center undertook in 1983 the development of a flammable-liquid detector for preboarding screening of passengers and their carry-on baggage. The ease with which Cubans from the Mariel boatlift have been able to carry bottled gasoline aboard air carrier aircraft made such a development necessary. In the laboratory, it has been possible to determine the vapor signatures of gasoline and gasoline's leakage rates from sealed containers. Doing this operationally, however, has proved difficult. Commercially available flammable-liquid detectors do not have the sensitivity needed to meet FAA's requirements. The center is pursuing the problem.

In April 1983, FAA hosted a conference of representatives from the federal government, universities, and industry to review past and present FAA explosive-detection programs and to suggest new methods. Recommendations of the 65 attendees, formed in working groups, were turned over to the center and FAA.

#### *Medical Safety Research*

FAA's Civil Aeromedical Institute at Oklahoma City researches medical aspects of aviation safety and publishes its findings in research studies.

The following were among studies published in 1983:

- *Crashworthiness: An Illustrated Commentary on Occupant Survival in General Aviation Accidents.* The illustrated commentary presents some basic concepts of crash dynamics and crash forces, explains the mechanisms responsible for injuries to occupants, and makes clear the value of effective restraints, including shoulder harnesses, lapbelts and properly designed and secured seats.
- *Characteristics of Medically Disqualified Airline Pilots.* The study—after summarizing the section in Federal Aviation Regulation Part 67 that specifies the physical and mental conditions that can result in denial of the first-class medical certificate to a pilot—examines the record to ascertain at what ages and why pilots had been denied certificates. The study found that age-specific denial rates for airline pilots increased with age to the highest rate interval, age 55–59, and that the most significant causes for denial were cardiovascular and neuropsychiatric.
- *Some Effects of Smoking Withdrawal on Complex Performance and Physiological Responses.* Seventeen habitual smokers, nine women and eight men, 23–59 years of age, were studied at simulated aircraft cabin altitudes of 2,000 meters. They were given monitoring, tracking, and problem-solving tasks to do, and their performance was measured while smoking and during withdrawal. The study found a significant drop in alertness and a tendency toward longer reaction times during withdrawal. The study suggested that the decrease in attentiveness during withdrawal might possibly require prohibition of smoking on the flight deck by air crew members.
- *An Analysis of Potential Protective Breathing Devices Intended for Use by Aircraft Passengers.* A series of tests evaluated concepts for developing an effective breathing device to protect aircraft passengers against toxic smoke and fumes from inflight fires. The study concluded that, of the devices tested, an oxygen mask modified to incorporate a controlled-use rebreather reservoir offered the best protection.

#### *Airport Pavement Research*

Congress, in the Airport and Airway Improvement Act of 1982, directed FAA to give top priority to improving aircraft braking and directional control on wet runways. Congress was especially concerned with runways used by turbojet aircraft, which have higher landing speeds and a greater potential for hydroplaning on wet runways than do other aircraft. Research by the agency in previous years has led the way. In the past

six years, 363 airports using federal airport development funds have improved one or more of their principal runways either by grooving the surfaces, using porous-friction-course overlays on them, or covering them with aggregate friction-seal courses or rubberized friction courses—improvements that FAA had helped develop in most instances.

Among present major research projects of the agency are studies to establish structural criteria for bearing high traffic levels at hub airports. Some existing pavement designs are extrapolations of post-World War II concepts, and their adequacy for present hub traffic requires verification. FAA is reviewing them with the Department of Defense and the U.S. Army Waterways Experimental Station at Vicksburg, Mississippi, which has also begun to study criteria for rigid and bituminous airport-runway overlays to find a more competitive approach.

FAA is exploring the practicability of building pavements from indigenous materials at remote sites where conventional building materials are not readily available. Local sand and silt, put under pressure in honeycomb mats, may be converted into uniform grids or cells several inches deep to form an unusually strong and easily constructed pavement. Such pavements have been successfully built by the military in Alaska and may be useful for remote utility airports. Criteria are being developed and validated for their possible use at airports where conventional materials cannot easily be justified because of cost.

In 1983, a pavement research project also was begun to develop a practicable mixed rubber and asphalt concrete that would use discarded rubber tires, a recyclable waste available throughout the country in great abundance. While there has as yet been no proof that the use of an extender of this sort will, when mixed with asphalt, make a safe and durable pavement, preliminary investigation suggests that there is a good possibility that it will. A contract was awarded and work begun on the mix specification, construction procedures, and quality control techniques required. When the research reaches the point that pavements incorporating a rubber-asphalt mix can be laid down, the ability to sustain heavy air traffic will be checked. If they prove durable, the savings of rubber-asphalt mix over asphalt will be impressive.

#### **Environmental Research**

In 1983, to carry out FAA's mission to limit adverse environmental effects of aviation, research centered on two principal areas: the reduction of helicopter noise and the control of aircraft engine emissions. In a third area, efforts were begun to establish an early warning system to limit harm from clouds of volcanic ash on inflight aircraft.

In 1982, FAA joined NASA and four major U.S. helicopter manufacturers in a five-year research pro-



gram to advance helicopter noise control and to improve ability to predict noise levels—aspects of the problem that are essential to FAA development of standards for civil helicopters. During the summer of 1983, FAA made noise measurements of seven modern helicopters at Dulles International Airport, which, with previous research in the area, will help formulate standards.

The Environmental Protection Agency revised its existing aircraft engine emission standards in 1983, making it necessary for FAA, under the Clean Air Act, to enforce these new standards. FAA issued regulations putting them into effect for newly manufactured engines in 1984.

During 1983, a new environmental research problem caused by an outbreak of volcanic eruptions throughout the world engaged the attention of FAA and NASA. Jet aircraft were increasingly flying into clouds of volcanic ash in the atmosphere and having to shut engines down when they began ingesting the ash. The solution was a system to detect ash-filled clouds, or volcanic plumes, in sufficient time for air traffic controllers to route traffic around them. FAA proposed to use the total-ozone-mapping system (TOMS) of NASA's *Nimbus 7* satellite to detect the volcanic plumes by their sulfur dioxide content. TOMS is believed to have the capability to detect the clouds; whether it is practical to provide information rapidly enough to route aircraft around them was being investigated by both agencies as 1983 ended.

## Air Navigation and Traffic Control

### *National Airspace System Plan*

FAA improved management, procurement, and contracting procedures to carry out the 450-page National Airspace Systems (NAS) Plan it had issued in January 1982 for modernizing its air navigation and traffic control system to meet the projected traffic demands of the next two decades. The plan called for replacing existing air traffic control computers with faster and more powerful units, introducing improved controller work stations with the latest state-of-the-art equipment, and upgrading the entire air traffic control function to higher levels of automation. Other key elements of the plan include acquiring improved radars, deploying an improved secondary radar system, establishing advanced airport landing aids, introducing new software add-ons to improve the automated air-traffic-control radar-terminal system, replacing outdated vacuum-tube communications and navigation equipment with the latest in solid-state technology, and upgrading at all levels the weather services provided to the nation's pilots. FAA recognized that to carry out the plan would require obligations of about \$10 billion for the first 10 years alone.

In April 1983, the agency issued an updated edition of the plan, detailing "the system definitions and subsystem decisions" made during the year to modernize the air navigation and air traffic control system. Four months later, the agency established a high-level, six-member Federal Aviation Advisory Committee, drawn in large part from the private sector, to provide independent analysis of the plan and its component programs.

### *En Route Air Traffic Control System*

The en route traffic control system was automated in the late 1960s and early 1970s. Its initial capabilities included the automatic processing and distribution of instrument flight rules (IFR) flight plans, automatic beacon and radar tracking of controlled aircraft, and presentation of aircraft location, identity, speed, and altitude on controller displays. In time, computer software and hardware enhancements and new microprocessors provided conflict alerts and minimum-safe-altitude warnings as well as a direct-access radar channel (DARC), which could take over and operate the air-route traffic control center's radar data-processing (RDP) system when the main computer complex failed or was shut down for maintenance. The basic problem at the control centers at the time the NAS plan was published was their central IBM 9020 computers. An excellent computer in its time, the 9020 is outdated and cannot take care of the projected traffic growth at the end of the decade or accommodate the higher levels of automation or the integration of the en route and terminal automation functions. To meet the near-term en route needs, the 9020 must be replaced by a host computer that will provide the hardware reliability and capacity for air traffic needs of the late 1980s and early 1990s. To meet the longer term needs for the 1990s and beyond, a total new automation system design will be required.

In December 1982, FAA issued a request for proposals for replacing the IBM 9020 computers. The new mainframe computers will be using the existing 9020 software. In September 1983, two major industry teams were awarded competitive design contracts for the new computer. They are to deliver their designs in early 1985, and plans are to award the production contract for the new host computer in mid-1985, with installation a year later. The new computers will provide for traffic at the largest centers through 1995, increase hardware reliability, and reduce energy consumption, as well as handle some additional air traffic control functions.

Concurrently with the host computer procurement, FAA will award contracts for the design, development, and production of an advanced automation system (AAS). The AAS is to be a total automation system that includes new controller sector suites (or work stations), new computer software, and a computer hard-

ware system built around an improved communications network. The new sector suites will replace today's radar displays and add an electronic flight-data-presentation capability, providing a more efficient environment for the controllers.

FAA issued a request for proposals for the AAS design competition in April 1983. Industry proposals were received in September 1983. The full deployment of the AAS is scheduled for 1992.

#### *Terminal Air Traffic Control Systems*

At the time the NAS plan was published, the radar terminal system included ARTS (automated radar terminal system) IIIs at 63 medium and high-density radar-terminals and 84 ARTS-II systems at low- and medium-traffic airports, whose traffic volume did not justify the much more expensive ARTS-III. The ARTS-III system was fully operational in the mid-1970s, the ARTS-II system in 1981.

Using broadband radar and digital alphanumeric in the same display, ARTS-III systems tracked airborne radar beacon traffic and informed terminal controllers of aircraft identity, altitude, and ground speed in digital, electrically written data tags that appeared on the radar displays beside the target radar "blips." Significant software enhancements were added to the basic system at the busiest terminals: conflict alert and minimum-safe-altitude warning, ability to track aircraft not equipped with transponders, and the software and hardware to take over and operate the system in any computer failure. Terminal systems with these capabilities were named ARTS-IIIs.

Under the NAS plan, the ARTS-IIIs will be upgraded further by adding sufficient memory to take care of traffic growth until the advanced automation system can replace ARTS. A contract for the additional memory will be awarded in March 1984, and it is expected to be in place at all ARTS-III terminals by April 1986.

The NAS plan also provides for upgrading the 84 ARTS-IIs in the system. This ARTS-II was built around a minicomputer that gave the controller a direct, alphanumeric readout of the identity and altitude of transponder-equipped aircraft whose radar beacon it was interrogating. Unlike the ARTS-III, however, it does not compute or display their ground speed. Nor does it track aircraft whose flight data it is receiving, whether they are transponder equipped or not. Under the NAS plan, add-on software and expanded computer capability will give the ARTS-IIs the same conflict-alert and minimum-safe-altitude capabilities as the en route centers and ARTS-III terminals, as well as the same aircraft-tracking ability. The development, begun in March 1982, was continued in 1983 and scheduled to be completed in May 1984.

#### *Ground-to-Air Systems*

FAA's ground-to-air systems include (in addition to the communications equipment tying them together) navigation aids, instrument landing systems, and primary and secondary radar surveillance systems. The NAS plan provided for the substantial upgrading of all three groups.

Under the plan, all existing vacuum-tube navigational aids, including the very-high-frequency omnidirectional ranges (VORs) with distance-measuring equipment and VORs with tactical air navigation units (VORTACs) will be replaced by 950 new solid-state VORs and VORTACs, a total sufficient to cover the entire country. The advanced design of the new aids will make them much more efficient than the vacuum-tube units and much less susceptible to failure. The new equipment will include remote-control maintenance, permitting adjustments from miles away without the need for costly trips to the transmitter site. Procurement is well advanced, and all VORs and VORTACs contracted for are expected to be in place by the year 2000. In addition, FAA plans to integrate all the navigation surveillance and communications facilities into "networks" that will ensure coverage of the country by a reduced number of facilities at significant savings over the existing system.

The need to replace the instrument landing system (ILS) was recognized in the late 1960s after a comprehensive review of the projected aviation needs through the year 2000. The microwave landing system (MLS) was developed and internationally adopted. In November 1981, the International Civil Aviation organization (ICAO) officially approved a transition from ILS to MLS and approved initial standards for the new system.

The MLS, with 1,250 units planned in the National Airspace System, is to be completely phased in around the world by the late 1990s. In addition to providing precision landing guidance to the full range of civil and military aircraft and for all landing categories, the MLS, unlike the ILS, is only minimally affected by surrounding terrain, structures, and weather conditions. And, again unlike the ILS, whose single-approach path limits airport capacity and exacerbates noise and congestion as traffic density increases, the MLS adapts well to noise-abatement procedures and provides an improved approach-and-landing capability ranging from a straight-in-approach to meet simple needs to a three-dimensional, wide-angle capability for curved approaches, permitting automatic landings on closely spaced runways in all weather conditions.

In 1978, FAA began service-testing three MLS prototype systems—a basic, wide-aperture system for large airports; a basic, narrow-aperture system for medium-size airports; and a small community system for small airports. Two commuter airlines and two helicopter operators made the tests, for development

by 1985 of the operational procedures and criteria. FAA and NASA also began to develop complex (curved) approach procedures. Engineering specifications for the MLS production contract were completed in 1982. In April 1983, the Secretary of Transportation approved procurement of all 1,250 MLS units called for in the NAS plan. That month, FAA issued a request for proposals to acquire the first 172 units over a five-year period. A contract for the 172 will be awarded early in 1984, with first units scheduled for installation in 1986.

A further key component of the NAS plan is the Mode S radar beacon system, a new secondary radar system of advanced ground sensors and radar beacon transponders that will replace the existing air-traffic-control radar-beacon system (ATCRBS) as the primary tracking and surveillance system for FAA's automated air traffic control. Mode S is superior to the present radar beacon system in that it interrogates transponder-equipped aircraft individually and selectively instead of calling all aircraft. This capability eliminates overlapping and garbled responses in congested airspace, provides more accurate positional information on the aircraft being interrogated, and avoids the radar beacon interference that is a problem with ATCRBS. Mode S also provides a channel for a future automatic data link between pilot and ground and opens the possibility of a whole new range of automatic safety services for the pilot.

Under development for the past several years, the Mode S system reached the procurement stage in 1983. A contract for 137 ground stations was expected to be awarded in May 1984, with the first delivery in 1987.

Delivery of the new long-range ARSR-3 air-route surveillance radars, procured in a previous period, was completed with the commissioning at Honolulu in January 1983 of the 23d and last radar.

In September, FAA let one of the largest radar contracts in the agency's history, for 137 ASR-9 airport-surveillance radars. The ASR-9s, which are of solid-state construction with built-in fault-detection and self-diagnostic capabilities, will begin delivery in 30 months. The new radar has separate channels for the detection of aircraft targets and weather. Unlike earlier air traffic control radars, the weather channel will be able to present six levels of weather intensity, permitting terminal controllers to guide pilots away from turbulence, wind gusts, lightning, and hail.

The NEXRAD next-generation Doppler-weather-radar project, a key program of the NAS plan, proceeded apace during the year. Jointly sponsored by the Departments of Commerce, Defense, and Transportation, the program is developing a network of common-use Doppler weather radars to meet the country's aviation needs in the 1990s and beyond. NEXRAD will replace today's outdated weather radars. The plan calls for definition, development, procurement, and in-

stallation of the system by the joint sponsors and for an initial procurement of a limited number of prototypes, followed by the rest of the production units. FAA's share of the cost is 20 percent of the total.

In August 1979, the NEXRAD Joint System's Program Office was established to plan and manage the procurement and eventual deployment of NEXRAD. In February 1982, two contracts were awarded in the design competition; by June 1983, both contracts had advanced to the validation and test of their designs. Under the announced schedule, the design and validation will continue until August 1986, when a prime contractor will be awarded a limited production contract for 10 units. NEXRAD is expected to become fully operational by 1992.

#### *Flight-Service-Station Modernization*

FAA has 317 flight service stations in the contiguous United States, Alaska, Hawaii, and Puerto Rico. The NAS plan provides for automating 61 stations and consolidating the remaining stations into the 61 automated facilities. A contract for the automated system was awarded in September 1981.

Two basic systems will be produced. Delivery, scheduled for completion by 1989, will be in three steps. Delivery of a model 1 system to provide limited specialist information (computerized weather information only) was scheduled to begin in 1984. It is to be followed by a model 2 system to provide full specialist information: automated weather information, charts, and graphics, plus limited user access to the computer data base. The final step would come with the addition of model 2 enhancements providing full, direct user access to the computer data base.

Of the 61 systems, 37 model 1s to be produced first are designed to permit later retrofit as enhanced model 2s. The remaining 24 systems will be delivered as enhanced model 2s in 1989 as the final stage of the procurement, with automation scheduled for completion in 1990.

Of particular value to the flight service stations in the future will be the development of the automated weather-observing system (AWOS). The system consists essentially of a number of standard weather sensors, including sensors for wind speed and wind direction, temperature, ceiling visibility, and dewpoint. A modular system was developed to produce immediate weather observations for pilots, controllers, flight service specialists, and others. Contracts for demonstration systems were awarded in 1982. Demonstrations of these systems began at 14 airport locations in 1983 to obtain user viewpoints. Installation of the first production units at airports is scheduled for 1986.

#### *Interfacility Communications Systems*

As a first step in modernizing its interfacility communication systems, FAA in late 1980 awarded a four-

year (1981-1985) multimillion-dollar contract for integrating all FAA interfacility communications into a single, nationwide computerized message switching system, the National Airspace Data Interchange Network (NADIN). This integration of ground-to-ground communications that tied together the air traffic control centers, towers, radar sites, and remote, ground-to-air transmitter sites had been needed for a long time; during the previous 40 years, a variety of separate, independently operated, low-speed communications networks had become increasingly costly to operate and could be neither expanded nor upgraded to meet future communication needs.

NADIN is a computerized system with two major message switches, one at the Atlanta center, the other at the Salt Lake City center. It also has computerized communications equipment, or concentrators, at 20 other sites. These would take care of the communica-

tion needs of flights operating between airport terminal areas in the 50 states and Puerto Rico and would serve as regional collection and dissemination points for messages originating at all of the agency's air traffic control facilities, including centers, airport control towers, and flight service stations. According to the plan, the Atlanta switch will collect and disseminate data from the eastern half of the country, and the Salt Lake City switch from the western half. The two switches will provide alternative routing to bypass failed or saturated areas. They will be mutually supporting, and each will be able to manage the entire system alone if necessary.

In 1982, the Salt Lake City switch was installed, as was the first concentrator. In 1983, the Atlanta switch and the remaining 20 concentrators were installed. Two switches were scheduled for commissioning in 1985.

# Environmental Protection Agency

In 1983, the Environmental Protection Agency (EPA) continued cooperation with NASA in two studies of fundamental atmospheric transport processes. These studies have helped to explain the role of cumulus clouds in long-range transport of air pollutants.

## PEPE/NEROS Results

In one study, data taken by NASA during the summer of 1980 as part of the field study called PEPE/NEROS (Persistent Elevated Pollutant Episode/North East Regional Oxidant Study) was analyzed. Data obtained with NASA's high-spectral-resolution lidar (HSRL) and ultraviolet-differential-absorption lidar (UV-DIAL) indicated that a parcel of air with high concentrations of ozone ( $O_3$ ) and aerosols drifted long distances above the boundary layer. This parcel of air did not encounter any rain systems during the period of the measurement.

## Cloud Venting Study

The field data of the other study was obtained in 1981. The NASA Electra aircraft, fitted with the HSRL and the UV-DIAL system, obtained data on ozone and aerosols during flights over North Carolina. These data, supplemented with in-situ measurements, surface sampling data, and back-trajectory studies, show that ozone gains entrance to the region of the troposphere above the boundary layer via clouds; that is by cumulus convection.

Data from this experiment provide substantial evidence that cloud pumping and cloud venting theories are indeed correct. Cloud pumping is typical of summer fair weather situations. Between noon and about 4 p.m., warm moist air rises, condenses, releases heat of condensation, becomes buoyant, and rises further. In this way white cumulus clouds—round on top, flat underneath—are born. Cumulus clouds are rooted in the boundary layer, their flat undersides marking its top. Depending on how moist the surrounding air is and other factors, cumulus clouds may enlarge; they may develop a head; they may thicken, become cumulo-nimbus clouds, and rain out; or they may remain thin and drift away, sometimes ultimately

evaporating. If it doesn't rain, the pollutants that cumulus clouds pump into the troposphere above the boundary layer remain there.

Although the hard data have been obtained only for ozone, cloud venting very likely transports all boundary layer pollutants, including sulfur dioxide and sulfate particles. Thus, cloud venting may be a key phenomenon on the long-range transport of acid rain and acid rain precursors.

The expensive phase, the gathering of field data, occurred in 1980 and 1981. Work in 1983 entailed some data analysis and the preparation of reports and papers.

## Future Activities

Analysis of the PEPE/NEROS data will likely continue for several years. The cloud venting work will be completed in 1984.

In the planning stage are future field experiments to elucidate cloud pumping further. In November 1983, EPA held a workshop at Research Triangle Park to design a Gulf Coast study. The Gulf Coast area is humid and therefore conducive to cumulus convection during summer fair weather conditions, an ideal situation for cloud pumping studies.

The HSRL and UV-DIAL systems used in these studies were developed by NASA with partial funding supplied by EPA's Interagency Energy/Environment Program. No cooperative development work on these remote measurement systems was done in 1983, but in 1984 NASA and EPA will be working together again under a new interagency agreement to advance UV-DIAL technology. An excimer laser, which NASA is developing for use on the Space Shuttle, will be evaluated for use in a smaller UV-DIAL system. The excimer laser is tunable and so theoretically should be capable of producing light pulses of the wavelength that can be absorbed by sulfur dioxide and ozone. Using it, the UV-DIAL system should be able to determine atmospheric level of both pollutants with a single laser. The ultimate goal is a small UV-DIAL system with low power requirements that can be operated from a light aircraft. This system will have many environmental applications, including acid rain studies.



# National Science Foundation

The National Science Foundation (NSF) supports research in both astronomy and atmospheric science. In the first area, NSF's 1983 support for ground-based and theoretical astronomy came through five grant programs benefiting more than 140 universities, plus backing for 5 National Astronomy Centers.

In atmospheric science, NSF provides the primary backing for research by both universities and private-sector groups in the United States. It also supports the National Center for Atmospheric Research (NCAR) and the Upper Atmospheric Facilities (UAF). NCAR, in Boulder, Colorado, conducts large scientific research programs that could not be done easily by a single university. The UAF supports four incoherent-scatter radar facilities in a chain stretching from Greenland through the United States and from Puerto Rico to Peru.

## Astronomy

Among major advances during 1983, scientists using optical telescopes at Cerro Tololo Inter-American Observatory in Chile witnessed the birth of a star—a first for astronomers—and discovered what may be the first black hole (superdense space object) found outside the Milky Way galaxy. Astronomers using a telescope at the National Astronomy and Ionosphere Center in Puerto Rico found the two fastest-spinning radio pulsars discovered in 15 years (see also Smithsonian Institution chapter). Another NAIC team spotted the first large nebula, or gas cloud, seen outside any galaxy.

More general achievements included discovery by observations at radio wavelengths of a gaseous interstellar medium rich in more than 60 species of molecules, many of them organic and complex. New and more sensitive electronic-array detectors made it possible to map radiating sources hundreds of times fainter and more distant than anything mapped before.

Astrophysicists were able to assess many of the effects of such phenomena as mass loss, binary star interactions, magnetic fields, and rotation on the structure and evolution of the stars. Observational work at radio, optical, gamma-ray, ultraviolet, and x-ray frequencies uncovered a profusion of explosive objects and high-energy, short-term phenomena. Their existence had been unknown before.

## Atmospheric Sciences

In 1983, atmospheric studies yielded new information about small-scale but severe weather systems, atmospheric chemistry, and climate in general. The probable benefits are noteworthy: immediate improvements in the accuracy of weather forecasts and warnings about such phenomena as lightning, better climate-prediction techniques, cost-effective and environmentally sound control strategies to deal with acid rain, and protection of the ozone layer.

Atmospheric scientists also studied El Niño, a periodic phenomenon that has preoccupied oceanographers for years. An upwelling of unusually warm water along the coast of Peru and Ecuador, El Niño apparently has a strong effect on climate in other parts of the world as well as in these countries. Atmospheric and ocean scientists hope that their research efforts—both individually and jointly—will result in better long-range forecasts and warnings about El Niño in the future.

NCAR scientists also made the surprising discovery that termites are a major source of the world's supply of methane gas. Though only a trace gas, methane seems to be increasing in the atmosphere and contributes to the well-known "greenhouse effect." The termites apparently produce large quantities of the gas as a byproduct of their digestive systems, which are anaerobic (active in the absence of free oxygen).

# Smithsonian Institution

The Smithsonian Institution supports national space goals through a broad and varied program of basic research at its Smithsonian Astrophysical Observatory (SAO) in Cambridge, Massachusetts, and through the exhibits, public programs, and educational activities of its National Air and Space Museum (NASM) in Washington. Research in both planetary science and space history are also conducted at NASM.

## Space Sciences

### *High-Energy Astrophysics*

Reduction and analysis of scientific data from the two High Energy Astronomy Observatory satellites (*HEAO 1* and 2, 1978–1981) continued in 1983. Research at SAO based on these data covered many astronomical topics, including stellar coronas, supernova remnants, globular star clusters, binary x-ray systems, various kinds of galaxies, BL Lac objects, quasars, clusters of galaxies, and identifications of x-ray sources with objects observed in other regions of the electromagnetic spectrum. Operation of the *Einstein* (*HEAO 2*) Guest Observer Program continued.

Analysis of data from the *HEAO 2* (*Einstein*) observatory satellite detected x-rays from the newly discovered “fast” radio pulsar, which is spinning about 20 times faster than the most rapid pulsar known until 1983; determined an x-ray luminosity function for quasars and strong evidence of evolution in luminosity with cosmic time; and developed an x-ray classification scheme for clusters of galaxies, with the conclusion that many galaxy clusters are dynamically young. It also found that clusters may be divided into two major classes—those with and without a dominant central galaxy—and that this dominant galaxy is present at an early stage in the cluster’s dynamical evolution.

In collaboration with scientists in the United States and in Europe, SAO researchers used *Einstein* stellar observations to obtain new information about stellar rotation, x-ray variability (especially in OB-type stars), and the structure of young stellar clusters. Interpretations of solar x-ray observations are being used to place constraints on solar-dynamo models and to yield greater insights into the structure and heating of the outer solar atmosphere. X-rays were also detected

from both polar regions of Jupiter, probably as the result of line emission from oxygen and sulfur ions migrating to the planet from volcanic eruptions on Io, Jupiter’s nearest large satellite.

### *Infrared Astronomy*

Infrared observations from the ground, NASA aircraft, and high-altitude balloons included imaging and spectroscopy of astronomical objects, such as regions of star formation and galaxies, and high-resolution spectroscopy of key molecules near the ozone layer in Earth’s stratosphere. For example, the flight of a balloon-borne one-meter telescope made far-infrared observations of star-forming regions in our galaxy as well as observations of the galactic center and diffuse emission from dust in the galactic plane. A far-infrared spectrometer was flown as part of the International Balloon Intercomparison Campaign in the spring of 1983 to assess the accuracy of the remote sensors for measuring constituents of the upper atmosphere.

### *Geophysics and Geodynamics*

The SAO laser satellite-tracking network continued tracking support of geophysical research at the observatory and at other institutions in the United States and abroad, as well as providing periodic mean positions of Earth’s pole of rotation. The upgraded laser system in Arequipa, Peru, operated at the prescribed specifications and achieved ranging accuracy within about three to five centimeters. The SAO laser from Natal, Brazil, was relocated to Matera, Italy, where it became operational in July. On October 31, SAO terminated all network operations and transferred its responsibilities to the Bendix Corporation. Thus, 1983 marked the last in an important and productive quarter century of SAO satellite tracking.

### *Solar and Stellar Physics*

Ultraviolet observations carried out with the International Ultraviolet Explorer (*IUE*) satellite encompassed a variety of research programs at SAO during 1983. Among them were *IUE* observations of the chromospherically active star Lambda Andromedae, which revealed the first ultraviolet flare recorded on a giant star, and perhaps the most energetic stellar flare

yet observed. Investigation of the optical and ultraviolet spectra of shock-wave regions in supernova remnants proceeded on several fronts. For example, optical spectra of remnants obtained at SAO's Whipple Observatory were combined with *IUE* observations to obtain abundance gradients in the M33 galaxy and to improve shock-model calculations.

### Planetary Sciences

SAO scientists continued to participate in analyzing data from the imaging experiment aboard the *Voyager 2* mission to Saturn. Highlights included discovery of optical evidence for electrostatic discharges in Saturn's Ring B, discovery of an active volcanic eruption on Jupiter's satellite Europa (following well-observed volcanic activity on the satellite Io), and detection of low-level activity on Europa during a close encounter of this satellite and the *Voyager 2* spacecraft.

Research at NASM's Center for Earth and Planetary Studies included analysis of remote-sensing

data from the advanced very-high-resolution radiometer (AVHRR) in an effort to discriminate, from orbit, specific terrestrial rock types based on their signatures in the infrared. Although originally taken by the National Oceanic and Atmospheric Administration for atmospheric studies, these data are now being used to classify surface materials in conjunction with more conventional orbital sensors. Over a test area in Saudi Arabia, the AVHRR data were significant in discriminating carbonate rock types from those with a greater silica content.

Investigations into the structural evolution of the planets indicated that the hereditary effects of ancient basins were more important on Earth's moon than on Mars. On the moon, topographic lows created by the impacts localized volcanic flooding, which later provided the driving force for vertical movements. In contrast, plains volcanism on Mars occurred over much broader areas. Compressional features in the Martian plains, as mapped from Viking orbiter images, indicate global-scale contraction coupled with regional sources of stress.

# Department of State

The United States continued in 1983 to pursue an expanding program of international cooperation in its civil space activities, with international activities increasing since the first operational flight of the Space Transportation System in November 1982 (see NASA chapter). In addition, the Administration encouraged the private sector to pursue commercial development for outer space and took actions to facilitate such endeavors.

International interest in remote sensing from space continued to grow, with other countries developing their own satellite systems. The French developed their SPOT system, to be launched in early 1984, and the Japanese are developing an Earth Resources Satellite (*ERS 1*) to be launched in the 1990s.

International interest and cooperation in space was reflected in plans of a number of new countries for the use of space. The openness and cooperative spirit of U.S. civil space programs continued to attract strong international scientific, technical, political, and commercial interest throughout 1983.

The Department of State works with NASA, Department of Defense, Office of Science and Technology Policy, National Oceanic and Atmospheric Administration, and National Security Council in formulating U.S. positions on international aspects of space policy. The department carried out its regular responsibilities in the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), United Nations General Assembly, International Telecommunications Satellite Organization (INTELSAT), and International Maritime Satellite Organization (INMARSAT).

## Activities within the United Nations

### *Outer Space Committee*

Within the United Nations, the 53-member Committee on the Peaceful Uses of Outer Space has served as a focal point for multilateral cooperation in the use and exploration of outer space and the further development of international law governing outer space activities. By the end of 1983, however, developments in the 38th General Assembly affecting the work of the committee raised serious questions about the ability of

the committee and its two subcommittees to function effectively in the future.

The committee began its 1983 cycle of meetings with the annual session of the Scientific and Technical Subcommittee in New York February 8-17, 1983. The 37th General Assembly in December 1982, acting on legal principles governing direct television broadcasting by satellite, had voted 107 to 13 (including the United States) against, with 13 abstaining—the first departure in the U.N. from the consensus principle covering the work of the committee. The 20th session of the Scientific and Technical Subcommittee, however, functioned relatively smoothly and effectively. The principal focus of the session was on the use of nuclear power sources in space, the U.N. Space Applications Program, and the implementation of the recommendations of the Second U.N. Conference on the Exploration and Use of Outer Space (UNISPACE '82), held in Vienna in August 1982. Because of concern in the subcommittee with the reentry of the Soviet nuclear reactor-powered satellite *Cosmos 1402*, the subcommittee recommended that a working group on nuclear power sources be reconvened at its 21st session in 1984 to review existing guidelines for use of nuclear sources. The subcommittee also recommended, following UNISPACE recommendations, that the committee undertake three technical studies on space technology (i.e., remote sensing, spacing satellites in the geosynchronous orbit, and educational direct-broadcast satellites).

The Legal Subcommittee's 22d session, in New York in March 1983, continued consideration of the legal implications of civil remote sensing of the earth from space, with the aim of formulating draft principles. It considered the possibility of supplementing the norms of international law on using nuclear power sources in space and also matters related to the definition and delimitation of outer space, including questions related to the geostationary satellite orbit. A number of issues continued to require resolution in the remote-sensing field, and little progress was achieved. The subcommittee did, however, agree on a text concerning the format and procedure for notification if a spacecraft carrying a nuclear power source malfunctioned. The subcommittee continued to be divided as to the need for new legal principles on a delimitation of outer space and the use of the geosynchronous orbit. The United States and

other Western delegations maintained that there was no practical or scientific basis for a delimitation of outer space and that discussion of the geosynchronous orbit should be left to the International Telecommunication Union.

In June 1983, the Committee on the Peaceful Uses of Outer Space met to review the work of the two subcommittees and to consider the UNISPACE '82 recommendations. The committee endorsed the recommendations proposed in the Scientific and Technical Subcommittee to convene expert groups to conduct three studies on space technology. It also endorsed the program of work proposed by the two subcommittees for 1984.

#### *U.N. General Assembly*

The 38th session of the General Assembly adopted by a vote of 124 to 12 against (including U.S.), with 8 abstentions, resolution 38/80, International Cooperation in the Peaceful Uses of Outer Space. That resolution is the omnibus resolution covering all activities associated with the Outer Space Committee, COPUOS, that is debated annually in the General Assembly and that previously has always been adopted by consensus. This year's resolution provides for COPUOS to take up subjects the United States and its allies believe are inappropriate to this committee's work, such as questions related to the "militarization" of outer space and the elaboration of legal principles to govern the geostationary satellite orbit. In explanation of its negative vote, the United States stated its view that COPUOS was embarked on an agenda of confrontation which, in the absence of any commitment to consensus, would mean an end to prospects for accomplishment and that the United States would have to reexamine its participation in COPUOS as a result.

### **Communications Satellites**

Space communications continued to be the most commercially oriented space application. The activities

of INTELSAT and INMARSAT continued to grow, with strong support from the U.S. government. U.S. industry remained the dominant supplier of communications satellites to the world community, with a number of satellite launches provided by NASA. Competition for launch services for INTELSAT satellites increased between the U.S. Space Shuttle and the European Ariane. U.S. commercial expendable launch vehicles may also compete in the near future.

The INMARSAT organization, providing communications services to ships at sea, is now operating and includes in its global satellite network the commercial capacity of the Marisat satellites (see also the Federal Communications Commission chapter). INMARSAT issued a request for proposals for its new generation of satellites, and U.S. industry is expected to play a major role in designing and constructing them.

### **Remote Sensing**

The department was represented on the Source Selection Board that drew up the request for proposals for commercial operation of land remote-sensing satellites. The State Department's concern has been to ensure that any arrangements reflect U.S. international space policies and obligations.

### **Technology Transfer**

The number of countries that seek to develop indigenous capability in satellite and launch vehicle technology is increasing as space technology matures and its economic importance is more widely appreciated. The number of requests for commercial transfers of space technology whose export must receive approval under export and munitions control regulations increased accordingly. The department coordinates an interagency effort to review the technology transfer issues and provide guidelines for specific actions as necessary.



# Arms Control and Disarmament Agency

Outer space arms control issues occupy an important place in the work of the U.S. Arms Control and Disarmament Agency. The agency participates in policy formulation for many of the United States activities in space.

The National Space Policy announced by the President July 4, 1982, stated that the United States will continue to study space arms control options. It will consider verifiable and equitable arms control measures that would ban or limit testing and deployment of specific weapon systems when compatible with national security.

During 1983, the agency participated in international discussions of outer space arms control and continued to examine the arms control aspects of U.S. space policy. It also continued to review the arms control implications of bilateral governmental space activities and sales of space-related items. In its research into outer space arms control options, and the many problems associated with such options, ACDA has worked closely with Department of Defense, Department of State, and NASA officials, as well as other U.S. government agencies.

## **International Discussions of Space Arms Control**

During 1983 the Committee on Disarmament in Geneva devoted considerable time to discussion of the agenda item, "Prevention of an Arms Race in Outer Space." ACDA provides the principal staffing and support for the U.S. delegation to the Committee on Disarmament, which meets in two sessions for a total of five months each year. A major issue was whether to form a working group to deal with the outer space issue. After intensive discussions, the Western Group (including the United States) proposed a mandate for the working group, with broad acceptance within the

committee; however, agreement on the mandate became impossible because of opposition late in the session by the Soviet bloc.

Another arena for serious discussion of outer space issues has been the First Committee (Arms Control Matters) of the United Nations General Assembly each fall. In 1982, the United States and the other Western allies laid the groundwork at the U.N. for their common position on outer space that later emerged at the Committee on Disarmament in Geneva. ACDA also participated in preparations for the U.N. Committee on the Peaceful Uses of Outer Space, where arms control issues have been discussed in spite of U.S. insistence that they properly belong in the Committee on Disarmament.

## **Space Policy**

ACDA has participated actively in the Senior Inter-agency Group (SIG) on Space, established by the President's 1982 space policy. The Director of ADCA is a member of the SIG; other ACDA officials have represented the agency in the Interagency Group (IG) on Space and in working groups established under the SIG, working closely with the National Security Council, the Department of Defense, the Department of State, the Department of Commerce, the intelligence community, the Organization of the Joint Chiefs of Staff, NASA, the Office of Management and Budget, the Office of Science and Technology Policy, and the Department of Transportation. ACDA was represented in the working groups that made recommendations to the SIG on the commercialization of expendable launch vehicles and on options for a permanently manned U.S. space station. ACDA will continue to participate in subsequent discussions of both issues and in SIG consideration of other policy issues.

# United States Information Agency

Promoting worldwide awareness of U.S. achievements in the exploration and peaceful uses of space continues to be a significant communications goal in the public diplomacy efforts of the U.S. Information Agency (USIA). Using direct satellite television and live radio broadcasting, on-the-spot news coverage, feature stories, interviews, exhibits, visits of astronauts to overseas posts, and video tape programs for TV, USIA focused on the Space Shuttle missions, stressing international cooperation in the launchings of the Canadian, Indonesian, and Indian satellites and the European Space Agency-built Spacelab, carried in the Shuttle.

Highlights of the 1983 Shuttle missions emphasized in USIA programming included the flights of the first U.S. woman astronaut, first black astronaut, and first German crew member. USIA countered Soviet disinformation activities that sought to discredit these achievements by accusing the United States of pursuing military aims.

The 25th anniversary of NASA afforded an opportunity to chronicle U.S. achievements in the exploration of space in the last quarter century and to look ahead to developments in the commercialization and industrialization of space.

## Space Shuttle

Live broadcasts by Voice of America (VOA) of launches and landings and up-to-the-minute coverage of missions in progress provided foreign audiences worldwide detailed news of the flights of the Shuttle orbiters *Challenger* and *Columbia*. Events were reported live from the launching and landing sites via a worldwide network in English. Selected events were also reported live in such languages as French, Spanish, Russian, Polish, Indonesian, and Hindi, which was also used by All India Radio. Of an estimated total VOA audience of 100 million listeners, thousands of letters from listeners indicated greatly increased audience for the space program broadcasts. More than 1,400 listeners requested VOA's Shuttle news references after only three VOA offers.

With NASA cooperation, the American Participant Program continued to arrange meetings of U.S. astronauts with foreign scientists, government officials, academics, and journalists. In 1983, six astronauts

visited a total of 15 countries. In April, Vance D. Brand spent a week supporting USIA efforts in Brazil. Dr. Don L. Lind visited Germany, Bahrain, and Egypt in June. Also in June, Dr. Franklin R. Chang-Diaz visited Colombia, Chile, and Uruguay. From September 24 through October 14, Dr. Sally K. Ride and Frederick H. Hauck were jointly programmed in the United Kingdom, The Netherlands, Belgium, Norway, Yugoslavia, Italy, Hungary, and Germany. Public response to the programs has been high.

The Wireless File, USIA's press service to 202 posts in 135 countries, also covered the Shuttle missions, scientific experiments, and improvements in Shuttle design, as well as NASA exhibits at the Paris Air Show in May. Emphasizing the deployment of the communications satellites, the Wireless File provided USIA posts numerous articles for background, post publications, and placement in the local press.

USIA magazines featured Space Shuttle missions. *America Illustrated*, the agency's monthly illustrated magazine sold in the Soviet Union under a reciprocal arrangement, highlighted the flight of *Columbia* in a cover story, "The Space Shuttle's Scientific and Commercial Uses." *Topic*, distributed in sub-Saharan Africa, analyzed benefits to mankind from the missions. The bimonthly *Problems of Communism* published essays and reviews of books on the politics of space, including the role of NASA and the *Columbia* mission.

The USIA television service included feature programs about the scientific achievements of the Shuttle flights and profiles of Dr. Ride and Guion S. Bluford on its weekly "TV Satellite File" for TV stations abroad. NASA film footage of Space Shuttles 7 and 8 was distributed to posts, and the television service produced a videotape program on the launching of *Insat I-B* for Indian TV. Cooperative ventures included a German TV production in cooperation with USIA/TV with a profile of a NASA engineer of German descent who participated in preparing for STS 7.

USIA provided visual materials for post-mounted exhibits in Izmir, Budapest, Prague, Warsaw, Moscow, Bucharest, Sofia, and Belgrade and filled 20 other post requests for display items such as space models, artifacts, spacesuits, space food tray, moon rocks, posters, booklets, and slides. It also assisted foreign institutions in mounting space exhibits. For example, "Space Science Exhibit," organized by the

Japanese L.I.C. International Company, toured 30 cities in Japan, and "The Great Space Shuttle Exhibition," organized by the America-Japan Society, was shown in 20 places in Japan.

### **Other Programs**

"Deep Space," a paper show distributed to 73 posts worldwide, covered recent U.S. achievements in the fields of astronomy, astrophysics, and radio and optical telescoping. The cover of the 1984 VOA calendar will carry a NASA photo from space, as will the new VOA poster in six language versions.

USIA's Exhibits Service is preparing the official U.S. participation in World's Fairs scheduled for 1985

and 1986. The U.S. national exhibition for Expo 85 World's Fair in Tsukuba, Japan, will include an exhibit on robotics in space. For Expo 86 in Vancouver, Canada, the topic for the U.S. exhibition will be "Exploration," emphasizing space ventures.

As *Pioneer 10* left the solar system in June, the Press Service's Wireless File recapped the spacecraft's adventures in space over the past 11 years. A 10-picture set on NASA's plans for planetary exploration through the year 2000 was sent to all posts.

To commemorate NASA's 25th anniversary, USIA/TV offered posts the NASA-produced documentary outlining the space agency's achievements. Exerpts were also used in USIA/TV's weekly "TV Satellite File."

# Appendixes

## APPENDIX A-1

### U.S. Spacecraft Record

(Includes spacecraft from cooperating countries launched by U.S. launch vehicles.)

Calendar Year	Earth Orbit <sup>a</sup>		Earth Escape <sup>a</sup>		Calendar Year	Earth Orbit <sup>a</sup>		Earth Escape <sup>a</sup>	
	Success	Failure	Success	Failure		Success	Failure	Success	Failure
1957	0	1	0	0	1971	45	2	8	1
1958	5	8	0	4	1972	33	2	8	0
1959	9	9	1	2	1973	23	2	3	0
1960	16	12	1	2	1974	27	2	1	0
1961	35	12	0	2	1975	30	4	4	0
1962	55	12	4	1	1976	33	0	1	0
1963	62	11	0	0	1977	27	2	2	0
1964	69	8	4	0	1978	34	2	7	0
1965	93	7	4	1	1979	18	0	0	0
1966	94	12	7	1 <sup>b</sup>	1980	16	4	0	0
1967	78	4	10	0	1981	20	1	0	0
1968	61	15	3	0	1982	21	0	0	0
1969	58	1	8	1	1983	31	0	0	0
1970	36	1	3	0	Total	1,029	134	79	15

<sup>a</sup> The criterion of success or failure used is attainment of earth orbit or earth escape rather than judgment of mission success. "Escape" flights include all that were intended to go to at least an altitude equal to lunar distance from the earth.

<sup>b</sup> This earth-escape failure did attain earth orbit and therefore is included in the earth-orbit success totals.

## APPENDIX A-2

### World Record of Space Launchings Successful in Attaining Earth Orbit or Beyond

(Enumerates launchings rather than spacecraft; some launches orbited multiple spacecraft.)

Calendar Year	United States	U.S.S.R.	France	Italy	Japan	People's Republic of China	Australia	United Kingdom	European Space Agency	India
1957		2								
1958	5	1								
1959	10	3								
1960	16	3								
1961	29	6								
1962	52	20								
1963	38	17								
1964	57	30								
1965	63	48	1							
1966	73	44	1							
1967	57	66	2	1			1			
1968	45	74								
1969	40	70								
1970	28	81	2	1 <sup>a</sup>	1	1				
1971	30	83	1	2 <sup>a</sup>	2	1		1		
1972	30	74		1	1					
1973	23	86								
1974	22	81		2 <sup>a</sup>	1					
1975	27	89	3	1	2	3				
1976	26	99			1	2				
1977	24	98			2					
1978	32	88			3	1				
1979	16	87			2			1		
1980	13	89			2					1
1981	18	98			3	1		2		1
1982	18	101			1	1				
1983	22	98		3	1			2		1
Total	814	1,636	10	8	24	11	1	1	5	3

<sup>a</sup> Includes foreign launchings of U.S. spacecraft.

## Successful U.S. Launches—1983

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
Jan. 26 <i>IRAS</i> 4A Delta 3910	Objective: To make first all-sky survey for objects that emit infrared radiation, provide a catalog of infrared sources and infrared sky maps.  Spacecraft: Satellite body is cylindrical, 3.6 m long, 2.16 m in diameter. Telescope system consists of telescope, focal-plane detectors and associated electronics, cryogenic equipment, insulation shield, sun and earth radiation shield, and interface skirt. Spacecraft system, mated to launch adapter and to infrared equipment, consists of 2 deployable solar panels, attitude control subsystem; data storage provided by redundant tape recorders. Weight at liftoff: 1,076 kg.	911 894 103.0 99.1	Cooperative U.S.-Netherlands-United Kingdom satellite launched by NASA. Onboard instruments detected unidentified cold astronomical objects, bands of dust in solar system, infrared cirrus clouds in interstellar space, infrared radiation from visually inconspicuous galaxies, 5 new comets, formation of new stars, possible beginnings of new solar systems around Vega and other stars. Spacecraft ceased operation Nov. 21. Still in orbit.
Feb. 9 Defense 8A Atlas H	Objective: Development of spaceflight techniques and technology.  Spacecraft: Not announced.	1,169 1,052 107.5 63.4	Launched by DoD with 8E and 8F in triple launch on 1 launch vehicle. Still in orbit.
Defense 8E	Objective: Development of spaceflight techniques and technology.  Spacecraft: Not announced.	1,156 1,060 107.4 63.4	Still in orbit.
Defense 8F	Objective: Development of spaceflight techniques and technology.  Spacecraft: Not announced.	1,156 1,160 107.4 63.4	Still in orbit.
March 28 <i>NOAA 8</i> 22A Atlas E	Objective: To launch spacecraft into sun-synchronous orbit of sufficient accuracy for dependable daytime and nighttime meteorological observations of the earth.  Spacecraft: Launch configuration including apogee kick motor (AKM), 4.91 m long, 1.88 in diameter. Structure composed of 4 major elements: reaction-control-equipment support structure (RSS), equipment support module (ESM), instrument mounting platform (IMP), and solar array. Instruments include advanced very-high-resolution radiometer (AVHRR), Argos data-collection system (DCS), space environment monitor (SEM) consisting of three sensors (total energy detector, medium-energy proton-electron detector, and high-energy proton-alpha detector), search and rescue (SAR) instruments, and Tiros operational vertical sounder (TOVS) composed of 3 instruments (high-resolution infrared-radiation sounder, stratospheric sounding unit, and microwave sounding unit). Search and rescue instruments, provided by Canada and France, capable of detecting and locating emergency transmitters operating at designated frequencies on earth. Weight at launch: 1,712 kg; weight in orbit after apogee motor firing; 1,030 kg.	829 806 101.2 98.8	First of Advanced Tiros-N (ATN) spacecraft; launched by NASA for National Oceanic and Atmospheric Administration. Stretched version of original Tiros-N series. Spacecraft attitude control problem corrected April 18. Operational June 20, 1983.
April 4 Space Shuttle <i>Challenger</i> (STS 6) 26 A	Objective: To deploy <i>TDRS 1</i> with IUS stage, accomplish assigned experiments and tests.  Spacecraft: Shuttle orbiter carrying satellite for tracking and data use, continuous-flow electrophoresis system (CFES), monodisperse latex reactor (MLR), nighttime-daytime optical survey of lightning (NOSL), 3 get-away specials (GASs), and aerodynamic-	284.3 284.3 94.5 28.45	Second operational flight of Space Transportation System. Orbiter <i>Challenger</i> piloted by astronauts Paul J. Weitz and Karol J. Bobko. Mission specialists were Donald H. Peterson and Story Musgrave. Shuttle lifted off from KSC at 1:30 p.m. EST. Satellite



## Successful U.S. Launches—1983

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
	<sup>4</sup> coefficient identification package (ACP). Total payload weight (including 1,860 kg for crew and crew equipment): 23,148 kg.		was deployed from cargo bay. First spacewalk (extravehicular activity; EVA) in more than 9 years, 3½-hour duration. <i>Challenger</i> landed on concrete runway at Edwards AFB, Calif., 1:53 p.m. EST, April 9. Total mission time: 5 days, 24 min. Orbiter was returned to KSC for overhaul for next flight.
<i>TDRS 1</i> 26B	Objective: To launch TDRS satellite to stationary geosynchronous orbit with sufficient stationkeeping propulsion fuel on board to meet support requirements and to initiate user support services; to provide improved tracking and data-acquisition services to spacecraft in low earth orbit. Spacecraft: Three-axis stabilized, momentum-biased configuration with sun-oriented solar panels attached. TDRS measures 14.4 m from tip to tip of deployed solar panels, 14.2 m from outer edge to edge of 2 deployed single-access antennas. TDRS composed of 3 modules: (1) equipment module houses attitude control, electrical power, propulsion, telemetry, tracking, and command subsystems; (2) payload module consists of processing and frequency-generation equipment; (3) antenna module supports deployable and fixed antennas, multiple-access array, and remainder of telecommunications hardware. Weight at launch, including IUS-1 upper stage: 20,328 kg.	35,806 35,762 1,435.9 1.7	Launched April 4 from Shuttle orbiter <i>Challenger</i> on first Shuttle-borne inertial upper stage (IUS-1). First of 3 Tracking and Data Relay Satellites (TDRS). IUS-1 malfunction prevented delivery to planned geosynchronous orbit. Subsequent series of 39 orbit-adjust firings by satellite's attitude control system maneuvered <i>TDRS 1</i> to geosynchronous altitude at 67° west longitude by June 1983. Leased by NASA, satellite supported STS 8 and STS 9 with Spacelab 1.
April 11 <i>RCA-Satcom 6</i> 30A Delta 3924	Objective: To place spacecraft in stationary geosynchronous orbit to provide TV, voice channels, and high-speed data transmission to Alaska, Hawaii, and contiguous U.S. Spacecraft: Box-shaped 1.2 × 1.2 × 1.6 m high; 2 rectangular solar panels on short booms give satellite span of 15.8 m. Hydrazine-propellant tanks protrude from east and west panels of spacecraft body. Three-axis stabilized. Weight in orbit, after apogee kick motor firing: 598.6 kg.	35,795 35,781 1,436.2 0.0	Second in new series of communications satellite launched by NASA for RCA. Satellite, to replace <i>RCA-Satcom 1</i> launched in 1975, placed above equator at 128° west longitude.
April 15 Defense 32A Titan IIIB	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	263 126 88.4 96.5	Reentered Aug. 21.
April 28 <i>GOES 6</i> 41A Delta 3914	Objective: To launch spacecraft into geosynchronous orbit to provide near-continual high-resolution, visual and infrared imaging over North and South America and surrounding oceans. Spacecraft: Cylindrical, 2.15 m in diameter and 4.43 m long from top of S-band omni antenna rod to bottom of apogee-boost motor. Weight at launch: 838 kg. Weight in orbit, after ejection of apogee-boost motor: 444 kg.	35,798 35,783 1,436.2 0.1	Launched by NASA for National Oceanic and Atmospheric Administration (NOAA), spacecraft joined <i>GOES 5</i> , launched May 1981, as part of two-satellite operational system. Apogee-boost motor fired April 30. Arrived on station May 12 at 135°W. longitude. Turned over to NOAA May 27; became operational June 1.

## Successful U.S. Launches—1983

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
May 19 <i>Intelsat-V F-6</i> 47A Atlas-Centaur	Objective: To place spacecraft in geosynchronous orbit for INTELSAT to provide 12,000 voice circuits and 2 color TV channels simultaneously. Spacecraft: Modular main body, 1.7 × 2 × 1.8 m, with winglike solar arrays spanning 15.6 m. Overall height, 6.4 m; width deployed, 6.8 m; 6 communications antennas—2 global-coverage horns, 2 hemispherical/zone offset-fed reflectors, and 2 offset-fed spot-beam reflectors. Double the capacity of Intelsat IV-A series. Weight at launch: 1,996 kg.	35,804 35,770 1,436.1 0.1	Sixth of series of 9 satellites; launched by NASA for 108-member-nation International Telecommunications Satellite Organization (INTELSAT). Placed in geosynchronous orbit after apogee-motor firing May 22; positioned over Atlantic Ocean.
May 26 <i>EXOSAT</i> 51A Delta 3914	Objective: To launch satellite with sufficient accuracy to permit it to accomplish its scientific mission, continuous observations of x-ray sources. Spacecraft: Box-shaped, covered in a superinsulating thermal blanket, 2.1 m in diameter, 1.35 m high and solar array 1.85 m high. Weight at liftoff: 500 kg, scientific payload accounting for 120 kg.	189,834 2,178 119.1 72.3	Launched by NASA for European Space Agency. Returning data.
June 9 Defense 56A Atlas H	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	1,165 1,050 107.4 63.4	Launched by DoD with satellite 56C in dual launch on 1 vehicle. Still in orbit.
Defense 56C	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced	1,164 1,052 107.4 63.4	Still in orbit.
June 18 Space Shuttle <i>Challenger</i> (STS 7) 59A	Objective: To launch <i>Anik C-2</i> (Telesat F), <i>Palapa B-1</i> ; complete assigned experiments and test objectives. Spacecraft: Shuttle orbiter carrying satellites <i>Anik C-2</i> , <i>Palapa B-1</i> , and reusable <i>SPAS 01</i> , as well as experiments CFES, MLR, and 7 get-away specials. Total payload weight (including 1,855 kg for crew and crew equipment): 18,631 kg.	296.3 296.3 90.3 28.4	Third operational flight of Space Transportation System. Orbiter <i>Challenger</i> piloted by Robert L. Crippen, Frederick H. Hauck. Mission specialists: John M. Fabian, Sally K. Ride (first woman astronaut), and Dr. Norman E. Thagard. Shuttle launched from KSC at 7:33 a.m. EDT. Deployed both communications satellites, carried out experiments including launching and recovering <i>SPAS 01</i> . <i>Challenger</i> landed at Edwards AFB, Calif., 9:57 a.m. EDT, June 24. Total mission time: 6 days, 2 hrs, 24 min. Orbiter returned to KSC for overhaul for next flight.
<i>Anik C-2</i> 59B	Objective: To launch satellite into transfer orbit permitting spacecraft propulsion system to place it in stationary synchronous orbit for communications coverage over Canada. Spacecraft: Cylindrical; in orbit, satellite deployed to height of 6.6 m. Spin-stabilized. Weight at launch: 4,443 kg.	35,796 35,777 1,436.1 0.0	Launched June 18 from Shuttle <i>Challenger</i> for Telesat Canada. In orbit.
<i>Palapa B-1</i> 59C	Objective: To launch satellite into transfer orbit of sufficient accuracy to permit spacecraft to achieve geosynchronous orbit for communications. Spacecraft: Cylindrical, identical to <i>Anik C-2</i> .	35,799 35,777 1,436.2 0.1	Launched June 19 from Shuttle <i>Challenger</i> for Republic of Indonesia. In orbit.

## Successful U.S. Launches—1983

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
SPAS 01 59F	Objective: To launch and retrieve reusable Shuttle Palet Satellite (SPAS). Spacecraft: Basic platform structure with complement of experiments. Managed by Messerschmitt-Bolkow-Blohm; GMBH, Space Division (MBB). Weight: 1,448 kg.	300 295 90.5 28.5	Deployed in free-flying orbit June 22 from Shuttle <i>Challenger</i> and then retrieved. Performed scientific experiments, tested remote manipulator arm, and photographed <i>Challenger</i> .
June 20 Defense 60a Titan 34 D	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	220 165 88.4 96.4	Launched by DoD with 60C on 1 launch vehicle. Still in orbit.
Defense 60C	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	1,287 1,284 111.3 96.7	Still in orbit.
June 27 HILAT (P83-1) 63A Scout	Objective: To place satellite into orbit permitting achievement of Air Force mission objectives. Satellite to evaluate certain propagation effects of disturbed plasmas on radar and communication systems. Spacecraft: Modified TRANSIT satellite. Weight: 102 kg.	833 767 100.9 82.0	Launched by NASA for USAF. Still in orbit.
June 28 Galaxy 1 65A Delta 3920	Objective: To launch spacecraft with sufficient accuracy to permit it to achieve stationary geosynchronous orbit for communications. Spacecraft: Cylindrical body, 216 cm in diameter, and 277 cm high in stowed launch configuration. In orbit, aft solar panel deploys, and antenna reflector erects for height of 683 cm. Weight: 519 kg.	35,794 35,778 1,436.1 0.0	Launched by NASA for Hughes Communications, Inc., positioned at 135° west longitude.
July 14 Navstar 8 72A Atlas E	Objective: To launch navigation satellite into planned orbit. Spacecraft: Same basic configuration as <i>Navstar 6</i> , launched in 1980. Weight: 873 kg.	20,446 19,917 718.0 62.8	Global Positioning System satellite launched by DoD in joint military services' developmental network. Still in orbit.
July 28 Telesat 3A 77A Delta 3920	Objective: To launch satellite with sufficient accuracy to permit PAM-D and spacecraft propulsion system to place spacecraft in stationary geosynchronous orbit. Spacecraft: Cylindrical body, 216 cm in diameter, and 274 cm in height in stowed configuration. Height with antennas and telescoping solar panel deployed, 684 cm. Weight in orbit: 653 kg.	35,794 35,781 1,436.2 0.0	Launched by NASA for American Telephone and Telegraph Company. Apogee boost motor fired July 29. Satellite on station at 87° west longitude above equator.
July 31 Defense 78A Titan IIIB	Objective: Development of spaceflight technique and technology. Spacecraft: Not announced.	Not available	Still in orbit.
Aug. 30 Space Shuttle <i>Challenger</i> (STS 8) 89A	Objective: To deploy <i>Insat 1-B</i> , and accomplish assigned experiments and test objectives. Spacecraft: Shuttle orbiter carrying satellite <i>Insat 1-B</i> , payload flight test article (PFTA), continuous-flow electrophoresis (CFES), 4 get-away-special experiments, and postal covers. Payload weight (without crew): 13,986 kg.	310 299 90.6 28.4	Fourth operational flight of Space Transportation System. <i>Challenger</i> piloted by astronauts Richard H. Truly, Daniel C. Brandenstein. Mission specialists: Dale A. Gardner, Guion S. Bluford, and Dr. William E. Thornton. <i>Challenger</i> lifted off from KSC at 2:32 a.m. EDT. Satellite was deployed from cargo bay Aug. 31. First night launch and landing, first black American in space (Bluford).

## Successful U.S. Launches—1982

Launch Date (GMT), Spacecraft Name, COSPAR Designation, Launch Vehicle	Mission Objectives, Spacecraft Data	Apogee and Perigee (km), Period (min), Inclination to Equator (°)	Remarks
			Orbiter <i>Challenger</i> landed on runway 22 at Edwards AFB, Calif., 3:41 a.m. EDT, Sept. 5. Total mission time: 6 days, 1 hr, 9 min. <i>Challenger</i> returned to KSC for overhaul and refurbishment.
<i>Insat 1B</i> 89B	Objective: To launch satellite into transfer orbit of sufficient accuracy to permit payload to achieve orbit for communications. Spacecraft: Box-shaped in stowed configuration; PAM-D attached to satellite body. Weight: 3,391 kg.	35,526 35,647 1,436.1 0.2	Launched from Shuttle Aug. 31 for government of India. Stuck solar array corected. Satellite operational in final parking slot at 74° east longitude, over equator south of India.
Sept. 8 <i>RCA-Satcom 7</i> (II R) 94A Delta 3924	Objective: To launch satellite into sufficiently accurate transfer orbit to permit spacecraft to achieve geosynchronous orbit. Spacecraft: Box-shaped 1.2 × 1.2 × 1.6 m high; 2 rectangular solar panels on short booms give satellite span of 15.8 m. Three-axis stabilized. Weight in orbit, after apogee kick motor fire: 598.6 kg.	35,805 35,771 1,436.2 0.1	Third in series of advanced satellites; launched by NASA for RCA to replace <i>RCA-Satcom 2</i> launched in 1976. Satellite placed above the equator at 72° west longitude.
Sept. 22 <i>Galaxy 2</i> 98A Delta 3920	Objective: To launch satellite with sufficient accuracy to permit the PAM-D and spacecraft propulsion system to place spacecraft in a stationary geosynchronous orbit for communications. Spacecraft: Cylindrical body, 216 cm in diameter and 277 cm high in stowed launch configuration. In orbit, aft solar panel deploys, and antenna reflector erects for height of 683 cm. Weight: 519 kg.	35,790 35,786 1,436.2 0.1	Second in series of 3 satellites, launched by NASA for Hughes Communications, Inc. Satellite stationed above equator at 74° west longitude.
Nov. 18 <i>DMSP F-7</i> 113A Atlas E	Objective: To launch meteorological observation satellite into planned orbit. Spacecraft: Same basic configuration as <i>DMSP F-6</i> . Weight: 1421 kg.	830 810 101.3 98.7	Launched by DoD and still in orbit. Second block 5D-2 spacecraft in Defense Meteorological Satellite Program (DMSP). Provides full earth coverage twice daily.
Nov. 28 Space Shuttle <i>Columbia</i> (STS 9) 116A	Objective: Primary, to verify Spacelab system and subsystem performance and capability, determine Spacelab-orbiter interface capability, and measure induced environment. Secondary objective: to obtain scientific, applications, and technology data from U.S.-European multidisciplinary payload and to demonstrate, to user community, broad capability of Spacelab for scientific research. Spacecraft: Shuttle orbiter carrying Spacelab 1 consisting of long tunnel and pressurized laboratory module plus exposed pallet, with scientific airlock and Spacelab window adapter assembly. Spacelab 1 carried more than 70 experiments in 5 areas of scientific research: astronomy and solar physics, space plasma physics, atmospheric physics and earth observations, life sciences, and materials science. Weight, including Spacelab, ancillary equipment, cables, fixtures, cargo bay equipment, not crew: 15,265 kg.	254 242 89.5 57.0	Fifth operational flight of Space Transportation System. Orbiter <i>Columbia</i> piloted by astronauts John W. Young, Brewster W. Shaw. Mission specialists: Owen K. Garriott and Robert A. R. Parker. Payload specialists Byron K. Lichtenberg and West German Ulf Merbold. <i>Columbia</i> lifted off from KSC at 11:00 a.m. EST. First flight of European-built Spacelab, first flight of 6-person crew, first flight of a payload specialist, and first flight of non-American on U.S. mission. <i>Columbia</i> landed on runway 17 at Edwards AFB, Calif., 6:47 p.m. EST, Dec. 8. Total mission time: 10 days, 7 hrs, 47 min. <i>Columbia</i> and Spacelab returned to KSC for overhaul and refurbishment for later flights.

## APPENDIX B-1

## U.S.-Launched Applications Satellites 1978-1983

Date	Name	Launch Vehicle	Remarks
COMMUNICATIONS			
Jan. 7, 1978	Intelsat IVA F-3	Atlas-Centaur	Positioned over Indian Ocean.
Feb. 9, 1978	Fltsatcom 1	Atlas-Centaur	First of new Defense series.
Mar. 5, 1978	Oscar 8	Thor-Delta (TAT)	Secondary payload with Landsat 3, replacement for Oscar 6 for amateur radio communications.
Mar. 31, 1978	Intelsat IVA F-6	Atlas-Centaur	Positioned over Indian Ocean.
Apr. 7, 1978	BSE (Yuri)	Thor-Delta (TAT)	Japanese experimental direct-broadcast satellite for television; domestic satellite.
May 11, 1978	OTS 2	Thor-Delta (TAT)	European Space Agency experimental relay satellite; domestic satellite.
June 29, 1978	Comstar D-3	Atlas-Centaur	Positioned south of U.S. over the equator by Comsat; domestic satellite.
Nov. 19, 1978	NATO IIIC	Thor-Delta (TAT)	Final one of this military series.
Dec. 14, 1978	DSCS II-11,12	Titan IIIC	Defense communications (dual launch).
Dec. 16, 1978	Anik 4 (Telesat D)	Thor-Delta (TAT)	Launched for Canada; domestic satellite.
May 4, 1979	Fltsatcom 2	Atlas-Centaur	Second of new DoD series.
Aug. 9, 1979	Westar 3	Thor-Delta (TAT)	Launched for Western Union Co. as part of its domestic communications links.
Nov. 21, 1979	DSCS II-13,14	Titan IIIC	Defense communications (dual launch).
Dec. 2, 1979	RCA-Satcom 3	Thor-Delta (TAT)	Launched for RCA, but contact lost during orbit circularization.
Jan. 18, 1980	Fltsatcom 3	Atlas-Centaur	Third of DoD series.
Oct. 31, 1980	Fltsatcom 4	Atlas-Centaur	Fourth of DoD series.
Nov. 15, 1980	SBS 1	Thor-Delta (TAT)	Launched for Satellite Business Systems as part of its domestic communications links.
Dec. 6, 1980	Intelsat V F-2	Atlas-Centaur	First of new series, positioned over Atlantic.
Feb. 21, 1981	Comstar D-4	Atlas-Centaur	Fourth in series for Comsat General Corp.
May 23, 1981	Intelsat V F-1	Atlas-Centaur	Second in series for INTELSAT, positioned over Atlantic.
Aug. 6, 1981	Fltsatcom 5	Atlas-Centaur	Fifth in DoD series.
Sept. 24, 1981	SBS 2	Thor-Delta (TAT)	Second in series for Satellite Business Systems.
Nov. 20, 1981	RCA-Satcom 3-R	Thor-Delta (TAT)	Fourth in series for RCA, replacement for RCA-Satcom 3.
Dec. 15, 1981	Intelsat V F-3	Atlas-Centaur	Third in series. To be positioned over Atlantic.
Jan. 16, 1982	RCA-Satcom 4	Thor-Delta (TAT)	Fifth in series for RCA.
Feb. 26, 1982	Westar 4	Thor-Delta (TAT)	First in a series of second-generation for Western Union Co.
Mar. 5, 1982	Intelsat V F-4	Atlas-Centaur	Fourth in series; positioned over Pacific.
Apr. 10, 1982	Insat 1A	Thor-Delta (TAT)	First in series for India Department of Space.
June 9, 1982	Westar 5	Thor-Delta (TAT)	Second in series of second-generation for Western Union Co.; replaces Westar 2.
Aug. 26, 1982	Anik D-1	Thor-Delta (TAT)	Launched for Telesat Canada as replacement for in-orbit satellites.
Sept. 28, 1982	Intelsat V F-5	Atlas-Centaur	Fifth in series; positioned over Indian Ocean.
Oct. 27, 1982	RCA-Satcom 5	Thor-Delta (TAT)	Joined 4 operational satellites launched for RCA.
Oct. 30, 1982	DSCS II, DSCS III	Titan III(34) D/IUS	Defense communications (dual launch), including first in series of uprated satellites.
Nov. 11, 1982	SBS 3	Space Shuttle, PAM-D	Third in series for Satellite Business Systems.
Nov. 12, 1982	Anik C-3	Space Shuttle, PAM-D	Second in new series for Telesat Canada.
Apr. 4, 1983	TDRS 1	Space Shuttle, IUS	First in series. System to provide continuous satellite communication. Leased by NASA from Space Communications Co. (Spacecom).
Apr. 11, 1983	RCA-Satcom 6	Delta 3924	Replacement for RCA-Satcom 1, launched for RCA.
May 19, 1983	Intelsat V F-6	Atlas-Centaur	Sixth in series; positioned over Atlantic Ocean.
June 18, 1983	Anik C-2	Space Shuttle, PAM-D	Launched for Telesat Canada.
June 19, 1983	Palapa B-1	Space Shuttle, PAM-D	Indonesian domestic communications.
June 28, 1983	Galaxy 1	Delta 3920/PAM-D	Launched for Hughes Communications, Inc.
July 28, 1983	Telstar 3A	Delta 3920/PAM-D	Launched for American Telephone and Telegraph Co.
Aug. 31, 1983	Insat 1-B	Space Shuttle, PAM-D	Indian domestic communications.
Sept. 8, 1983	RCA-Satcom 7	Delta 3924	Replacement for RCA-Satcom 2, launched for RCA.
Sept. 22, 1983	Galaxy 2	Delta 3920/PAM-D	Second in series, launched for Hughes Communications, Inc.
WEATHER OBSERVATION <sup>a</sup>			
May 1, 1978	AMS 3	Thor-Burner 2	DoD meteorological satellite.
June 16, 1978	GOES 3	Thor-Delta (TAT)	Third of this series for NOAA.
Oct. 13, 1978	Tiros-N	Atlas F	First of third-generation for NOAA, also experimental satellite for NASA.



## U.S.-Launched Applications Satellites 1978-1983

Date	Name	Launch Vehicle	Remarks
Oct. 24, 1978	Nimbus 7	Thor-Delta (TAT)	Last of this experimental series for NASA.
June 6, 1979	AMS 4	Atlas F	DoD meteorological satellite.
June 27, 1979	NOAA 6	Atlas F	Second of 8 planned third-generation satellites for NOAA; first was Tiros-N.
May 29, 1980	NOAA-B	Atlas F	Failed to achieve useful orbit.
Sept. 9, 1980	GOES 4	Thor-Delta (TAT)	Fourth of this series for NOAA.
May 22, 1981	GOES 5	Thor-Delta (TAT)	Fifth of polar-orbiting series for NOAA.
June 23, 1981	NOAA 7	Atlas F	Replacement for NOAA-B.
Dec. 21, 1982	DMSP F-6	Atlas E	DoD meteorological satellite.
Mar. 28, 1983	NOAA 8	Atlas E	Joined NOAA 7 as part of 2-satellite operational system; launched for NOAA.
Apr. 28, 1983	GOES 6	Delta 3914	Launched for NOAA, operational as GOES-West.
Nov. 18, 1983	DMSP F-7	Atlas E	Second in block 5D-2 series, DoD meteorological satellite.
EARTH OBSERVATION			
Mar. 5, 1978	Landsat 3	Thor-Delta (TAT)	Third experimental earth resources satellite.
Apr. 26, 1978	HCMM (AEM 1)	Scout	Experimental, low-cost, limited-function heat-capacity mapping mission for earth resources.
June 27, 1978	Seasat 1	Atlas F	Proof-of-concept oceanographic-phenomena data-collection satellite.
July 16, 1982	Landsat 4	Thor-Delta (TAT)	Fourth experimental earth resources satellite. First use of thematic mapper (TM).
GEODESY			
Apr. 9, 1975	Geos 3	Thor-Delta (TAT)	To measure geometry and topography of ocean surface.
May 4, 1976	Lageos	Thor-Delta (TAT)	Laser geodynamic satellite.
NAVIGATION			
Feb. 22, 1978	Navstar 1	Atlas F	Global Positioning System satellite.
May 13, 1978	Navstar 2	Atlas F	Global Positioning System satellite.
Oct. 7, 1978	Navstar 3	Atlas F	Global Positioning System satellite.
Dec. 11, 1978	Navstar 4	Atlas F	Global Positioning System satellite.
Feb. 9, 1980	Navstar 5	Atlas F	Global Positioning System satellite.
Apr. 26, 1980	Navstar 6	Atlas F	Global Positioning System satellite.
May 15, 1981	Nova 1	Scout	First of improved Transit system satellites, for DoD.
July 14, 1983	Navstar 8	Atlas E	Global Positioning System satellite.

<sup>a</sup>Does not include Department of Defense weather satellites that are not individually identified by launch.

## APPENDIX B-2

## U.S.-Launched Scientific Satellites 1978-1983

Date	Name	Launch Vehicle	Remarks
Jan. 26, 1978	IUE	Thor-Delta (TAT)	Ultraviolet observation of astronomical phenomena, in elliptical geosynchronous orbit.
July 14, 1978	Geos 2	Thor-Delta (TAT)	European studies of magnetosphere, in geosynchronous orbit.
Aug. 12, 1978	ISEE 3	Thor-Delta (TAT)	International Sun-Earth Explorer in halo orbit near earth-sun libration point; moved in 1983 to path to meet Comet Giacobini-Zinner in 1985.
Oct. 24, 1978	Cameo	Thor-Delta (TAT)	Barium and lithium cloud experiments, carried in rocket body of Nimbus 7 launcher.
Nov. 13, 1978	Heao 2	Atlas-Centaur	High-resolution observations of astronomical x-ray sources.
Jan. 30, 1979	Scatha	Thor-Delta (TAT)	Measurement of sources of electric charge buildup on spacecraft.
Feb. 18, 1979	Sage	Scout	Measurement of stratospheric aerosols and ozone.
Feb. 24, 1979	Solwind	Atlas F	Measurement of solar wind, electron buildup in polar regions, aerosols, and ozone.
June 6, 1979	Ariel 6	Scout	Measurement of cosmic radiation (United Kingdom payload).
Sept. 20, 1979	Heao 3	Atlas-Centaur	Gamma and cosmic ray emissions.
Oct. 30, 1979	Magsat	Scout	Detailed current description of earth's magnetic field and of sources of variations.
Feb. 14, 1980	SMM	Thor-Delta (TAT)	Solar Maximum Mission.
Aug. 3, 1981	Dynamics Explorers 1, 2	Thor-Delta (TAT)	DE 1 and 2 to measure magnetospheric-ionospheric energy coupling, electric currents and fields, plasmas.
Oct. 6, 1981	SME	Thor-Delta (TAT)	Solar Mesosphere Explorer to measure changes in mesospheric ozone.
Oct. 6, 1981	UOSAT (Oscar 9)	Thor-Delta (TAT)	Secondary payload with SME, for amateur radio and science experiments.
Jan. 26, 1983	IRAS	Delta 3910	Infrared sky survey.
May 26, 1983	EXOSAT	Delta 3914	European Space Agency study of x-ray sources.
June 22, 1983	SPAS 01	Space Shuttle	Reusable free-flying platform deployed and retrieved during STS 7; 6 scientific experiments from West Germany, 2 from ESA. NASA experiments tested spacecraft technology.
June 27, 1983	HILAT (P83-1)	Scout	Propagation effects of disturbed plasma on radar and communication systems, for DoD.

## U.S.-Launched Space Probes 1975-1983

Date	Name	Launch Vehicle	Remarks
Aug. 20, 1975	Viking 1	Titan IIIE-Centaur	Lander descended, landed safely on Mars on Plains of Chryse, Sept. 6 1976, while orbiter circled planet photographing it and relaying all data to Earth. Lander photographed its surroundings, tested soil samples for signs of life, and took measurements of atmosphere.
Sept. 9, 1975	Viking 2	Titan IIIE-Centaur	Lander descended, landed safely on Mars on Plains of Utopia, July 20, 1976, while orbiter circled planet photographing it and relaying all data to Earth. Lander photographed its surroundings, tested soil samples for signs of life, and took measurements of the atmosphere.
Jan. 15, 1976	Helios 2	Titan IIIE-Centaur	Flew in highly elliptical orbit to within 41 million km of sun, measuring solar wind, corona, electrons, and cosmic rays. Payload had same West German and U.S. experiments as Helios 1 plus cosmic-ray burst detector.
Aug. 20, 1977	Voyager 2	Titan IIIE-Centaur	Jupiter and Saturn flyby mission. Swung around Jupiter in July 1979, arrived Saturn in 1981, going on to Uranus by 1986, Neptune by 1989.
Sep. 5, 1977	Voyager 1	Titan IIIE-Centaur	Jupiter and Saturn flyby mission. Passing Voyager 2 on the way, swung around Jupiter in Mar. 1979, arrived at Saturn in Nov. 1980, headed for outer solar system.
May 20, 1978	Pioneer Venus 1	Atlas-Centaur	Venus orbiter; achieved Venus orbit Dec. 4, returning imagery and data.
Aug. 8, 1978	Pioneer Venus 2	Atlas-Centaur	Carried 1 large, 3 small probes plus spacecraft bus; all descended through Venus atmosphere Dec. 9, returned data.

## APPENDIX C

## U.S. and Soviet Manned Spaceflights 1961-1983

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Vostok 1	Apr. 12, 1961	Yuriy A. Gagarin	0 : 1 : 48	First manned flight.
Mercury- Redstone 3	May 5, 1961	Alan B. Shepard, Jr.	0 : 0 : 15	First U.S. flight; suborbital.
Mercury- Redstone 4	July 21, 1961	Virgil I. Grissom	0 : 0 : 16	Suborbital; capsule sank after landing; astronaut safe.
Vostok 2	Aug. 6, 1961	German S. Titov	1 : 1 : 18	First flight exceeding 24 h.
Mercury-Atlas 6	Feb. 20, 1962	John H. Glenn, Jr.	0 : 4 : 55	First American to orbit.
Mercury-Atlas 7	May 24, 1962	M. Scott Carpenter	0 : 4 : 56	Landed 400 km beyond target.
Vostok 3	Aug. 11, 1962	Andriyan G. Nikolayev	3 : 22 : 25	First dual mission (with Vostok 4).
Vostok 4	Aug. 12, 1962	Pavel R. Popovich	2 : 22 : 59	Came within 6 km of Vostok 3.
Mercury-Atlas 8	Oct. 3, 1962	Walter M. Schirra, Jr.	0 : 9 : 13	Landed 8 km from target.
Mercury-Atlas 9	May 15, 1963	L. Gordon Cooper, Jr.	1 : 10 : 20	First U.S. flight exceeding 24 h.
Vostok 5	June 14, 1963	Valeriy F. Bykovskiy	4 : 23 : 6	Second dual mission (with Vostok 6).
Vostok 6	June 16, 1963	Valentina V. Tereshkova	2 : 22 : 50	First woman in space; within 5 km of Vostok 5.
Voskhod 1	Oct. 12, 1964	Vladimir M. Komarov Konstantin P. Feoktistov Boris G. Yegorov	1 : 0 : 17	First 3-man crew.
Voskhod 2	Mar. 18, 1965	Pavel I. Belyayev Aleksey A. Leonov	1 : 2 : 2	First extravehicular activity (Leonov, 10 min).
Gemini 3	Mar. 23, 1965	Virgil I. Grissom John W. Young	0 : 4 : 53	First U.S. 2-man flight; first manual maneuvers in orbit.
Gemini 4	June 3, 1965	James A. McDivitt Edward H. White II	4 : 1 : 56	21-min extravehicular activity (White).
Gemini 5	Aug. 21, 1965	L. Gordon Cooper, Jr. Charles Conrad, Jr.	7 : 22 : 55	Longest-duration manned flight to date.
Gemini 7	Dec. 4, 1965	Frank Borman James A. Lovell, Jr.	13 : 18 : 35	Longest-duration manned flight to date.
Gemini 6-A	Dec. 15, 1965	Walter M. Schirra, Jr. Thomas P. Stafford	1 : 1 : 51	Rendezvous within 30 cm of Gemini 7.
Gemini 8	Mar. 16, 1966	Neil A. Armstrong David R. Scott	0 : 10 : 41	First docking of 2 orbiting spacecraft (Gemini 8 with Agena target rocket).
Gemini 9-A	June 3, 1966	Thomas P. Stafford Eugene A. Cernan	3 : 0 : 21	Extravehicular activity; rendezvous.
Gemini 10	July 18, 1966	John W. Young Michael Collins	2 : 22 : 47	First dual rendezvous (Gemini 10 with Agena 10, then Agena 8).
Gemini 11	Sept. 12, 1966	Charles Conrad, Jr. Richard F. Gordon, Jr.	2 : 23 : 17	First initial-orbit docking; first tethered flight; highest earth-orbit altitude (1,372 km).
Gemini 12	Nov. 11, 1966	James A. Lovell, Jr. Edwin E. Aldrin, Jr.	3 : 22 : 35	Longest extravehicular activity to date (Aldrin, 5 hrs 37 min).
Soyuz 1	Apr. 23, 1967	Vladimir M. Komarov	1 : 2 : 37	Cosmonaut killed in reentry accident.
Apollo 7	Oct. 11, 1968	Walter M. Schirra, Jr. Donn F. Eisele R. Walter Cunningham	10 : 20 : 9	First U.S. 3-man mission.
Soyuz 3	Oct. 26, 1968	Georgiy T. Beregovoy	3 : 22 : 51	Maneuvered near unmanned Soyuz 2.
Apollo 8	Dec. 21, 1968	Frank Borman James A. Lovell, Jr. William A. Anders	6 : 3 : 1	First manned orbit(s) of moon; first manned departure from earth's sphere of influence; highest speed attained in manned flight to date.
Soyuz 4	Jan. 14, 1969	Vladimir A. Shatalov	2 : 23 : 23	Soyuz 4 and 5 docked and transferred 2 cosmonauts from Soyuz 5 to Soyuz 4.
Soyuz 5	Jan. 15, 1969	Boris V. Volynov Aleksey S. Yeliseyev Yevgeniy V. Khrunov	3 : 0 : 56	
Apollo 9	Mar. 3, 1969	James A. McDivitt David R. Scott Russell L. Schweickart	10 : 1 : 1	Successfully simulated in earth orbit operation of lunar module to landing and takeoff from lunar surface and rejoining with command module.
Apollo 10	May 18, 1969	Thomas P. Stafford John W. Young Eugene A. Cernan	8 : 0 : 3	Successfully demonstrated complete system including lunar module descent to 14,300 m from the lunar surface.
Apollo 11	July 16, 1969	Neil A. Armstrong Michael Collins Edwin E. Aldrin, Jr.	8 : 3 : 9	First manned landing on lunar surface and safe return to earth. First return of rock and soil samples to earth, and manned deployment of experiments on lunar surface.
Soyuz 6	Oct. 11, 1969	Georgiy Shonin Valeriy N. Kubasov	4 : 22 : 42	Soyuz 6, 7, and 8 operated as a group flight without actually docking. Each conducted certain experiments, including welding and earth and celestial observation.
Soyuz 7	Oct. 12, 1969	Anatoliy V. Filipchenko Viktor N. Gorbatko Vladislav N. Volkov	4 : 22 : 41	
Soyuz 8	Oct. 13, 1969	Vladimir A. Shatalov Aleksey S. Yeliseyev	4 : 22 : 50	

## U.S. and Soviet Manned Spaceflights 1961-1983

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Apollo 12	Nov. 14, 1969	Charles Conrad, Jr. Richard F. Gordon, Jr. Alan L. Bean	10 : 4 : 36	Second manned lunar landing. Explored surface of moon and retrieved parts of Surveyor 3 spacecraft, which landed in Ocean of Storms on Apr. 19, 1967.
Apollo 13	Apr. 11, 1970	James A. Lovell, Jr. Fred W. Haise, Jr. John L. Swigert, Jr.	5 : 22 : 55	Mission aborted; explosion in service module. Ship circled moon, with crew using LM as "lifeboat" until just before reentry.
Soyuz 9	June 1, 1970	Andriyan G. Nikolayev Vitaliy I. Sevastyanov	17 : 16 : 59	Longest manned spaceflight to date.
Apollo 14	Jan. 31, 1971	Alan B. Shepard, Jr. Stuart A. Roosa Edgar D. Mitchell	9 : 0 : 2	Third manned lunar landing. Mission demonstrated pinpoint landing capability and continued manned exploration.
Soyuz 10	Apr. 22, 1971	Vladimir A. Shatalov Aleksey S. Yeliseyev Nikolay N. Rukavishnikov	1 : 23 : 46	Docked with Salyut 1, but crew did not board space station launched 19 Apr. Crew recovered Apr. 24, 1971.
Soyuz 11	June 6, 1971	Georgiy T. Dobrovolskiy Vladislav N. Volkov Viktor I. Patsayev	23 : 18 : 22	Docked with Salyut 1 and Soyuz 11 crew occupied space station for 22 days. Crew perished during final phase of Soyuz 11 capsule recovery on June 30, 1971.
Apollo 15	July 26, 1971	David R. Scott Alfred M. Worden James B. Irwin	12 : 7 : 12	Fourth manned lunar landing and first Apollo "J" series mission, which carried Lunar Roving Vehicle. Worden's inflight EVA of 38 min 12 sec. was performed during return trip.
Apollo 16	Apr. 16, 1972	John W. Young Charles M. Duke, Jr. Thomas K. Mattingly II	11 : 1 : 51	Fifth manned lunar landing, with Lunar Roving Vehicle.
Apollo 17	Dec. 7, 1972	Eugene A. Cernan Harrison H. Schmitt Ronald E. Evans	12 : 13 : 52	Sixth and final Apollo manned lunar landing, again with roving vehicle.
Skylab 2	May 25, 1973	Charles Conrad, Jr. Joseph P. Kerwin Paul J. Weitz	28 : 0 : 50	Docked with Skylab 1 (launched unmanned May 14) for 28 days. Repaired damaged station.
Skylab 3	July 28, 1973	Alan L. Bean Jack R. Lousma Owen K. Garriott	59 : 11 : 9	Docked with Skylab 1 for more than 59 days.
Soyuz 12	Sept. 27, 1973	Vasiliy G. Lazarev Oleg G. Makarov	1 : 23 : 16	Checkout of improved Soyuz.
Skylab 4	Nov. 16, 1973	Gerald P. Carr Edward G. Gibson William R. Pogue	84 : 1 : 16	Docked with Skylab 1 in long-duration mission; last of Skylab program.
Soyuz 13	Dec. 18, 1973	Petr I. Klimuk Valentin V. Lebedev	7 : 20 : 55	Astrophysical, biological, and earth resources experiments.
Soyuz 14	July 3, 1974	Pavel R. Popovich Yuriy P. Artyukhin	15 : 17 : 30	Docked with Salyut 3 and Soyuz 14 crew occupied space station.
Soyuz 15	Aug. 26, 1974	Gennadiy V. Sarafanov Lev S. Demin	2 : 0 : 12	Rendezvoused but did not dock with Salyut 3.
Soyuz 16	Dec. 2, 1974	Anatoliy V. Filipchenko Nikolay N. Rukavishnikov	5 : 22 : 24	Test of ASTP configuration.
Soyuz 17	Jan. 10, 1975	Aleksey A. Gubarev Georgiy M. Grechko	29 : 13 : 20	Docked with Salyut 4 and occupied station.
Anomaly	Apr. 5, 1975	Vasiliy G. Lazarev Oleg G. Makarov	0 : 0 : 20	Soyuz stages failed to separate; crew recovered after abort.
Soyuz 18	May 24, 1975	Petr I. Klimuk Vitaliy I. Sevastyanov	62 : 23 : 20	Docked with Salyut 4 and occupied station.
Soyuz 19	July 15, 1975	Aleksey A. Leonov Valeriy N. Kubasov	5 : 22 : 31	Target for Apollo in docking and joint experiments of ASTP mission.
Apollo (ASTP)	July 15, 1975	Thomas P. Stafford Donald K. Slayton Vance D. Brand	9 : 1 : 28	Docked with Soyuz 19 in joint experiments of ASTP mission.
Soyuz 21	July 6, 1976	Boris V. Volynov Vitaliy M. Zholobov	48 : 1 : 32	Docked with Salyut 5 and occupied station.
Soyuz 22	Sept. 15, 1976	Valeriy F. Bykovskiy Vladimir V. Aksenov	7 : 21 : 54	Earth resources study with multispectral camera system.



## U.S. and Soviet Manned Spaceflights 1961–1983

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Soyuz 23	Oct. 14, 1976	Vyacheslav D. Zudov Valeriy I. Rozhdestvenskiy	2 : 0 : 6	Failed to dock with Salyut 5.
Soyuz 24	Feb. 7, 1977	Viktor V. Gorbato Yuriy N. Glazkov	17 : 17 : 23	Docked with Salyut 5 and occupied station.
Soyuz 25	Oct. 9, 1977	Vladimir V. Kovalenok Valeriy V. Ryumin	2 : 0 : 46	Failed to achieve hard dock with Salyut 6 station.
Soyuz 26	Dec. 10, 1977	Yuriy V. Romanenko Georgiy M. Grechko	37 : 10 : 6	Docked with Salyut 6. Crew returned in Soyuz 27; crew duration 96 days 10 hrs.
Soyuz 27	Jan. 10, 1978	Vladimir A. Dzhanibekov Oleg G. Makarov	64 : 22 : 53	Docked with Salyut 6. Crew returned in Soyuz 26; crew duration 5 days 22 hrs 59 min.
Soyuz 28	Mar. 2, 1978	Aleksey A. Gubarev Vladimir Remek	7 : 22 : 17	Docked with Salyut 6. Remek was first Czech cosmonaut to orbit.
Soyuz 29	June 15, 1978	Vladimir V. Kovalenok Aleksandr S. Ivanchenkov	79 : 15 : 23	Docked with Salyut 6. Crew returned in Soyuz 31; crew duration 139 days 14 hrs 48 min.
Soyuz 30	June 27, 1978	Petr I. Klimuk Miroslaw Hermaszewski	7 : 22 : 4	Docked with Salyut 6. Hermaszewski was first Polish cosmonaut to orbit.
Soyuz 31	Aug. 26, 1978	Valeriy F. Bykovskiy Sigmund Jaehn	67 : 20 : 14	Docked with Salyut 6. Crew returned in Soyuz 29; crew duration 7 days 20 hrs 49 min. Jaehn was first German Democratic Republic cosmonaut to orbit.
Soyuz 32	Feb. 25, 1979	Vladimir A. Lyakhov Valeriy V. Ryumin	108 : 4 : 24	Docked with Salyut 6. Crew returned in Soyuz 34; crew duration 175 days 36 min.
Soyuz 33	Apr. 10, 1979	Nikolay N. Rukavishnikov Georgi I. Ivanov	1 : 23 : 1	Failed to achieve docking with Salyut 6 station. Ivanov was first Bulgarian cosmonaut to orbit.
Soyuz 34	June 6, 1979	(unmanned at launch)	73 : 18 : 17	Docked with Salyut 6, later served as ferry for Soyuz 32 crew while Soyuz 32 returned unmanned.
Soyuz 35	Apr. 9, 1980	Leonid I. Popov Valeriy V. Ryumin	55 : 1 : 29	Docked with Salyut 6. Crew returned in Soyuz 37. Crew duration, 184 days 20 hrs 12 min.
Soyuz 36	May 26, 1980	Valeriy N. Kubasov Bertalan Farkas	65 : 20 : 54	Docked with Salyut 6. Crew returned in Soyuz 35. Crew duration 7 days 20 hrs 46 min. Farkas was first Hungarian to orbit.
Soyuz T-2	June 5, 1980	Yuriy V. Malyshev Vladimir V. Aksenov	3 : 22 : 21	Docked with Salyut 6. First manned flight of new-generation ferry.
Soyuz 37	July 23, 1980	Viktor V. Gorbato Pham Tuan	79 : 15 : 17	Docked with Salyut 6. Crew returned in Soyuz 36. Crew duration 7 days 20 hrs 42 min. Pham was first Vietnamese to orbit.
Soyuz 38	Sept. 18, 1980	Yuriy V. Romanenko Arnaldo Tamayo Mendez	7 : 20 : 43	Docked with Salyut 6. Tamayo was first Cuban to orbit.
Soyuz T-3	Nov. 27, 1980	Leonid D. Kizim Oleg G. Makarov Gennadiy M. Strekalov	12 : 19 : 8	Docked with Salyut 6. First 3-man flight in Soviet program since 1971.
Soyuz T-4	Mar. 12, 1981	Vladimir V. Kovalenok Viktor P. Savinykh	74 : 18 : 38	Docked with Salyut 6.
Soyuz 39	Mar. 22, 1981	Vladimir A. Dzhanibekov Jugderdemidiyn Gurragcha	7 : 20 : 43	Docked with Salyut 6. Gurragcha first Mongolian cosmonaut to orbit.
Space Shuttle Columbia (STS 1)	Apr. 12, 1981	John W. Young Robert L. Crippen	2 : 6 : 21	First flight of Space Shuttle, tested spacecraft in orbit. First landing of airplanelike craft from orbit for reuse.
Soyuz 40	May 14, 1981	Leonid I. Popov Dumitru Prunariu	7 : 20 : 41	Docked with Salyut 6. Prunariu first Romanian cosmonaut to orbit.
Space Shuttle Columbia (STS 2)	Nov. 12, 1981	Joe H. Engle Richard H. Truly	2 : 6 : 13	Second flight of Space Shuttle, first scientific payload (OSTA 1). Tested remote manipulator arm. Returned for reuse.
Space Shuttle Columbia (STS 3)	Mar. 22, 1982	Jack R. Lousma C. Gordon Fullerton	8 : 4 : 49	Third flight of Space Shuttle, second scientific payload (OSS 1). Second test of remote manipulator arm. Flight extended 1 day because of flooding at primary landing site; alternate landing site used. Returned for reuse.
Soyuz T-5	May 13, 1982	Anatoliy Berezhovoy Valentin Lebedev	211 : 9 : 5	Docked with Salyut 7. Crew duration of 211 days. Crew returned in Soyuz T-7.
Soyuz T-6	June 24, 1982	Vladimir Dzhanibekov Aleksandr Ivanchenkov Jean-Loup Chretien	7 : 21 : 51	Docked with Salyut 7. Chretien first French cosmonaut to orbit.

## U.S. and Soviet Manned Spaceflights 1961-1983

Spacecraft	Launch Date	Crew	Flight Time (days : hrs : min)	Highlights
Space Shuttle Columbia (STS 4)	June 27, 1982	Thomas K. Mattingly II Henry W. Hartsfield, Jr.	7 : 1 : 9	Fourth flight of Space Shuttle, first DoD payload, additional scientific payloads. Returned July 4. Completed orbital flight testing program. Returned for reuse.
Soyuz T-7	Aug. 19, 1982	Leonid Popov Aleksandr Serebrov Svetlana Savitskaya	7 : 21 : 52	Docked with Salyut 7. Savitskaya second Soviet woman to orbit. Crew returned in Soyuz T-5.
Space Shuttle Columbia (STS 5)	Nov. 11, 1982	Vance D. Brand Robert F. Overmyer Joseph P. Allen William B. Lenoir	5 : 2 : 14	Fifth flight of Space Shuttle, first operational flight; launched 2 commercial satellites (SBS 3 and Anik C-3); first flight with 4 crewmembers. EVA test canceled when spacesuits malfunctioned.
Space Shuttle Challenger (STS 6)	Apr. 4, 1983	Paul J. Weitz Karol J. Bobko Donald H. Peterson Story Musgrave	5 : 0 : 24	Sixth flight of Space Shuttle, launched TDRS 1.
Soyuz T-8	Apr. 20, 1983	Vladimir Titov Gennady Strekalov Aleksander Serebrov	2 : 0 : 18	Failed to achieve docking with Salyut 7 station.
Space Shuttle Challenger (STS 7)	June 18, 1983	Robert L. Crippen Frederick H. Hauck John M. Fabian Sally K. Ride Norman T. Thagard	6 : 2 : 24	Seventh flight of Space Shuttle, launched 2 commercial satellites (Anik C-2 and Palapa B-1), also launched and retrieved SPAS 01; first flight with 5 crewmembers, including first woman U.S. astronaut.
Soyuz T-9	June 28, 1983	Vladimir Lyakhov Aleksandr Aleksandrov	149 : 9 : 46	Docked with Salyut 7 station.
Space Shuttle Challenger (STS 8)	Aug. 30, 1983	Richard H. Truly Daniel C. Brandenstein Dale A. Gardner Guion S. Bluford, Jr. William E. Thornton	6 : 1 : 9	Eighth Flight of Space Shuttle, launched one commercial satellite (Insat 1-B), first flight of U.S. black astronaut
Space Shuttle Columbia (STS 9)	Nov. 28, 1983	John W. Young Brewster W. Shaw Owen K. Garriott Robert A. R. Parker Byron K. Lichtenberg Ulf Merbold	10 : 7 : 47	Ninth flight of Space Shuttle, first flight of Spacelab 1, first flight of 6 crewmembers, one of whom was West German, first non-U.S. astronaut to fly in U.S. space program.

## APPENDIX D

## U.S. Space Launch Vehicles

Vehicle	Stages	Propellant <sup>a</sup>	Thrust (kilo- newtons)	Max. Dia. × Height (m)	Max. Payload (kg) <sup>b</sup>			First Launch <sup>c</sup>
					185-Km Orbit	Geosynch. Transfer Orbit	Circular Sun-Synch. Orbit	
Scout	1. Algol IIIA .....	Solid .....	431.1	1.14 × 22.9	255	—	155 <sup>d</sup>	1979(60)
	2. Castor IIA .....	Solid .....	285.2		205 <sup>d</sup>			
	3. Antares IIIA .....	Solid .....	83.1					
	4. Altair IIIA .....	Solid .....	25.6					
Delta 2900 Series (Thor-Delta)	1. Thor plus .....	LOX/RP-1 .....	912.0	2.44 × 35.4	2,000	705	1,250 <sup>d</sup>	1973(60)
	9 TX 354-5 .....	Solid .....	147 each		1,410 <sup>d</sup>			
	2. Delta .....	N <sub>2</sub> O <sub>4</sub> /Aerozine-50 ..	44.2					
Delta 3900 Series (Thor-Delta) <sup>e</sup>	3. TE 364-4 .....	Solid .....	65.8	2.44 × 35.4	3,045	1,275	2,135 <sup>d</sup>	1982(60)
	1. Thor plus .....	LOX/RP-1 .....	912.0		2,180 <sup>d</sup>			
	9 TX 526-2 .....	Solid .....	375 each					
	2. Delta .....	N <sub>2</sub> O <sub>4</sub> /Aerozine-50 ..	44.2					
Atlas E	1. Atlas booster & sustainer .....	LOX/RP-1 .....	1,722.0	3.05 × 28.1	2,090 <sup>d f</sup>	—	1,500 <sup>d</sup>	1972(67)
Atlas-Centaur	1. Atlas booster & sustainer .....	LOX/RP-1 .....	1,913.0	3.05 × 45.0	6,100	2,360	—	1,984(62)
	2. Centaur .....	LOX/LH <sub>2</sub> .....	146.0					
					185-Km Orbit	Direct Geosynch. Orbit	Sun- Synch. Transfer Orbit	
Titan IIIB-Agena	1. LR-87 .....	N <sub>2</sub> O <sub>4</sub> /Aerozine .....	2,341.0	3.05 × 48.4	3,600 <sup>d</sup>	—	3,060 <sup>d</sup>	1966
	2. LR-91 .....	N <sub>2</sub> O <sub>4</sub> /Aerozine .....	455.1					
	3. Agena .....	IRFNA/UDMH .....	71.2					
Titan III(34)D/ IUS	1. Two 5½-segment, 3.05 m dia .....	Solid .....	11,564.8	3.05 × 48.0	14,920	1,850 <sup>d</sup>	—	1982
	2. LR-87 .....	N <sub>2</sub> O <sub>4</sub> /Aerozine .....	2,366.3					
	3. LR-91 .....	N <sub>2</sub> O <sub>4</sub> /Aerozine .....	449.3					
	4. IUS 1st stage .....	Solid .....	275.8					
	5. IUS 2nd stage .....	Solid .....	115.7					
Titan III(34)D/ Transtage	Same as Titan III(34)D plus: 4. Transtage .....	N <sub>2</sub> O <sub>4</sub> /Aerozine .....	69.8	3.05 × 46.9	14,920	1,855 <sup>d</sup>	—	1984 <sup>h</sup>
					280- to 420-Km Orbit			
Space Shuttle (reusable)	1. Orbiter; 3 main engines (SSMEs) fire in parallel with SRBs .....	LOX/LH <sub>2</sub> .....	1,670 each	23.79 × 37.24 wing long span	29,500 in full performance configuration			1981
	2. Two-solid-fueled rocket boosters (SRBs) fire in parallel with SSMEs .....	AL/NH <sub>4</sub> ClO <sub>4</sub> / PBAN .....	11,790 each					
	Mounted on ex- ternal tank (ET) .....				3.71 × 45.45			
				8.40 × 46.88				

<sup>a</sup> Propellant abbreviations used are as follows: liquid oxygen and a modified kerosene = LOX/RP,RJ; solid propellant combining in a single mixture both fuel and oxidizer = solid; inhibited red-fuming nitric acid and unsymmetrical dimethylhydrazine = IRFNA/UDMH; nitrogen tetroxide and UDMH/N<sub>2</sub>H<sub>4</sub> = N<sub>2</sub>O<sub>4</sub>/aerozine; liquid oxygen and liquid hydrogen = LOX/LH<sub>2</sub>; aluminum, ammonium perchlorate, and polybutadiene acrolonitrile terpolymer = AL/NH<sub>4</sub>ClO<sub>4</sub>/PBAN.

<sup>b</sup> Due east launch except as indicated.

<sup>c</sup> The date of first launch applies to this latest modification with a date in parentheses for the initial version.

<sup>d</sup> Polar launch.

<sup>e</sup> Maximum performance based on 3920, 3920/PAM configurations. PAM = payload assist module (a private venture).

<sup>f</sup> With dual TE 364-4.

<sup>g</sup> With 96° flight azimuth.

<sup>h</sup> Initial operational capability in December 1982; launch to be scheduled as needed.

NOTE: Data should not be used for detailed NASA mission planning without concurrence of the director of Space Transportation System Support Programs.

## APPENDIX E-1

## Space Activities of the U.S. Government

## HISTORICAL BUDGET SUMMARY — BUDGET AUTHORITY

(in millions of dollars)

Fiscal Year	NASA		Defense	Energy	Com- merce	Interior	Agricul- ture	NSF	Total Space
	Total	Space <sup>a</sup>							
1959 .....	330.9	260.9	489.5	34.3	...	...	...	...	784.7
1960 .....	523.6	461.5	560.9	43.3	...	...	...	0.1	1,065.8
1961 .....	964.0	926.0	813.9	67.7	...	...	...	.6	1,808.2
1962 .....	1,824.9	1,796.8	1,298.2	147.8	50.7	...	...	1.3	3,294.8
1963 .....	3,673.0	3,626.0	1,549.9	213.9	43.2	...	...	1.5	5,434.5
1964 .....	5,099.7	5,016.3	1,599.3	210.0	2.8	...	...	3.0	6,831.4
1965 .....	5,249.7	5,137.6	1,573.9	228.6	12.2	...	...	3.2	6,955.5
1966 .....	5,174.9	5,064.5	1,688.8	186.8	26.5	...	...	3.2	6,969.8
1967 .....	4,965.6	4,830.2	1,663.6	183.6	29.3	...	...	2.8	6,709.5
1968 .....	4,587.3	4,430.0	1,921.8	145.1	28.1	0.2	0.5	3.2	6,528.9
1969 .....	3,990.9	3,822.0	2,013.0	118.0	20.0	.2	.7	1.9	5,975.8
1970 .....	3,745.8	3,547.0	1,678.4	102.8	8.0	1.1	.8	2.4	5,340.5
1971 .....	3,311.2	3,101.3	1,512.3	94.8	27.4	1.9	.8	2.4	4,740.9
1972 .....	3,306.6	3,071.0	1,407.0	55.2	31.3	5.8	1.6	2.8	4,574.7
1973 .....	3,406.2	3,093.2	1,623.0	54.2	39.7	10.3	1.9	2.6	4,824.9
1974 .....	3,036.9	2,758.5	1,766.0	41.7	60.2	9.0	3.1	1.8	4,640.3
1975 .....	3,229.1	2,915.3	1,892.4	29.6	64.4	8.3	2.3	2.0	4,914.3
1976 .....	3,550.3	3,225.4	1,983.3	23.3	71.5	10.4	3.6	2.4	5,319.9
Transitional Quarter .....	931.8	849.2	460.4	4.6	22.2	2.6	.9	.6	1,340.5
1977 .....	3,817.8	3,440.2	2,411.9	21.7	90.8	9.5	6.3	2.4	5,982.8
1978 .....	4,060.1	3,622.9	2,738.3	34.4	102.8	9.7	7.7	2.4	6,518.2
1979 .....	4,595.5	4,030.4	3,035.6	58.6	98.4	9.9	8.2	2.4	7,243.5
1980 .....	5,240.2	4,680.4	3,848.4	39.6	92.6	11.7	13.7	2.4	8,688.8
1981 .....	5,518.4	4,992.4	4,827.7	40.5	87.0	12.3	15.5	2.4	9,977.8
1982 .....	6,043.9 <sup>b</sup>	5,527.6	6,678.7	60.6	144.5	12.1	15.2	2.0	12,440.7
1983 .....	6,875.3 <sup>c</sup>	6,327.9	9,018.9	38.9	177.8	4.6	20.4	0.0 <sup>d</sup>	15,588.5
1984 est. ....	7,217.5	6,590.4	10,590.3	34.1	234.8	4.7	23.0	0.0 <sup>d</sup>	17,477.3
1985 est. ....	7,491.4	6,804.3	12,912.7	33.5	254.6	4.2	16.0	0.0 <sup>d</sup>	20,025.3

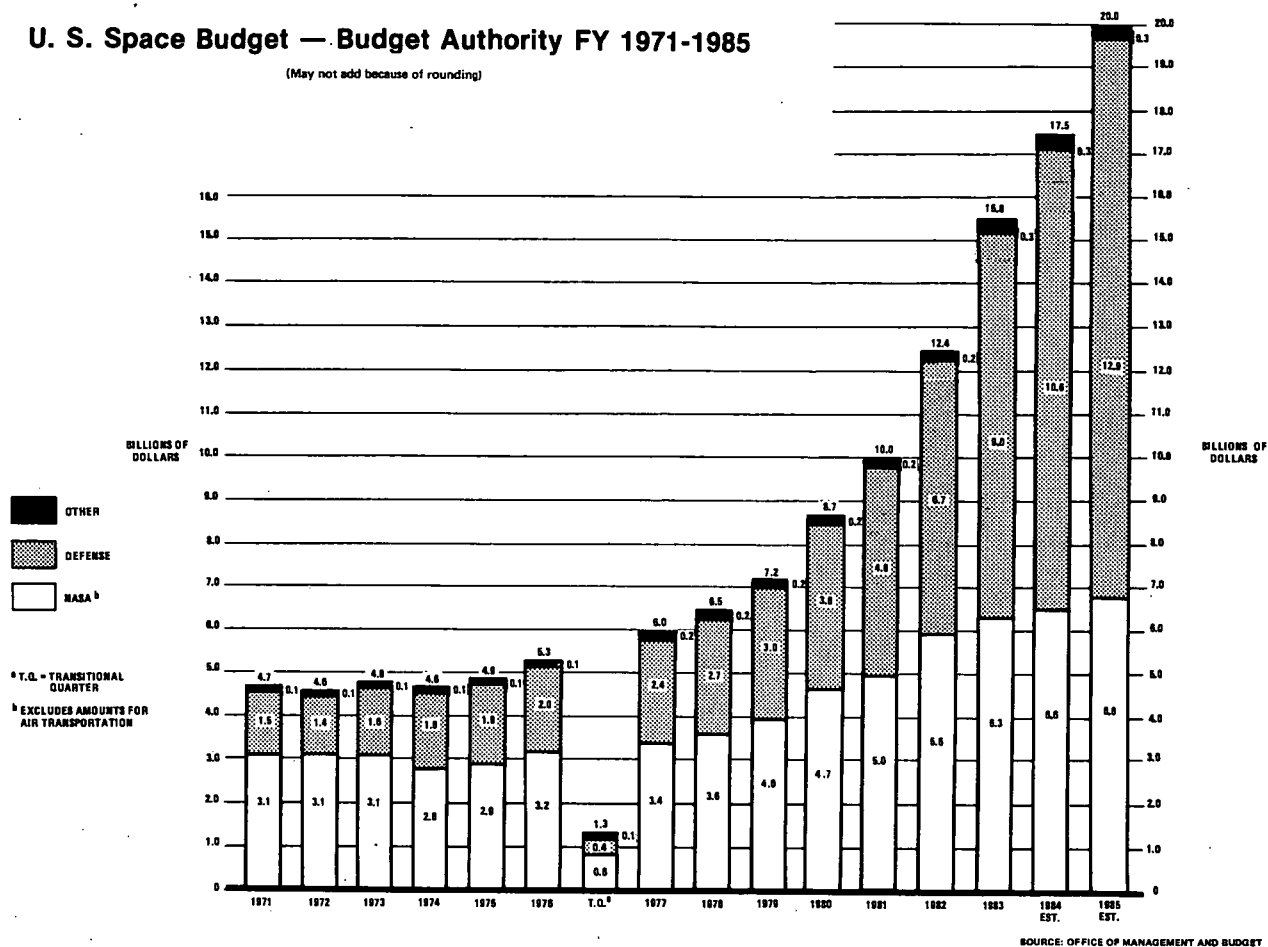
<sup>a</sup> Excludes amounts for air transportation (subfunction 402).

SOURCE: Office of Management and Budget.

<sup>b</sup> Includes \$33.5 million unobligated funds that lapsed.<sup>c</sup> Includes \$37.6 million for reappropriation of prior year funds.<sup>d</sup> NSF funding of balloon research transferred to NASA.

# U. S. Space Budget — Budget Authority FY 1971-1985

(May not add because of rounding)



## APPENDIX E-2

### Space Activities Budget

(in millions of dollars by fiscal year)

Federal Space Programs	Budget Authority			Budget Outlays		
	1983 Actual	1984 Estimate	1985 Estimate	1983 Actual	1984 Estimate	1985 Estimate
<b>Federal agencies:</b>						
NASA <sup>a</sup>	6,327.9	6,590.4	6,804.3	6,100.9	6,426.8	6,676.6
Defense	9,018.9	10,590.3	12,912.7	6,246.7	8,062.1	10,888.4
Energy	38.9	34.1	33.5	39.6	37.2	35.0
Commerce	177.8	234.8	254.6	178.0	234.9	254.3
Interior	4.6	4.7	4.2	4.8	4.7	4.3
NSF <sup>b</sup>	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	20.4	23.0	16.0	20.4	23.0	16.0
<b>Total</b>	<b>15,588.5</b>	<b>17,477.3</b>	<b>20,025.3</b>	<b>12,590.4</b>	<b>14,788.7</b>	<b>17,874.6</b>
<b>NASA:</b>						
Space flight	4,085.4	4,047.5	3,821.0	4,052.8	4,091.0	3,884.2
Space science, applications, and technology	1,596.0	1,735.0	2,018.8	1,486.2	1,589.6	1,898.6
Air transportation	547.4	627.1	687.1	563.0	641.4	693.4
Supporting operations	646.5	807.9	964.5	561.9	746.2	893.8
<b>Total NASA</b>	<b>6,875.3</b>	<b>7,217.5</b>	<b>7,491.4</b>	<b>6,663.9</b>	<b>7,068.2</b>	<b>7,370.0</b>

<sup>a</sup> Excludes amounts for air transportation. Includes \$37.6 million for reappropriation of prior year funds.

<sup>b</sup> NSF funding for balloon research transferred to NASA.

SOURCE: Office of Management and Budget.



## Aeronautics Budget

(in millions of dollars by fiscal year)

Federal Aeronautics Programs	Budget Authority			Budget Outlays		
	1983 Actual	1984 Estimate	1985 Estimate	1983 Actual	1984 Estimate	1985 Estimate
NASA <sup>a</sup> .....	547.4	627.1	687.1	563.0	641.4	693.4
Department of Defense <sup>b</sup> .....	3,220.9	3,807.0	4,466.3	2,920.1	3,642.3	4,192.3
Department of Transportation <sup>c</sup> .....	103.0	263.5	269.0	71.2	192.3	252.0
Total .....	3,871.3	4,697.6	5,422.4	3,554.3	4,476.0	5,137.7

<sup>a</sup> Research and Development, Construction of Facilities, Research and Program Management.

<sup>b</sup> Research, Development, Testing, and Evaluation of aircraft and related equipment.

<sup>c</sup> Federal Aviation Administration: Research, Engineering, and Development; Facilities, Engineering, and Development.

SOURCE: Office of Management and Budget.

## Expendable Launch Vehicles: Presidential Policy Announcement

*Announcement of U.S. Government Support for Commercial Operations by the Private Sector. May 16, 1983*

The President today announced that the U.S. Government fully endorses and will facilitate commercial operations of Expendable Launch Vehicles (ELV's) by the U.S. private sector. This policy applies to both those ELV's previously developed for U.S. Government use, as well as new space launch systems developed specifically for commercial applications. This policy is consistent with the President's National Space Policy and represents a positive step toward encouraging U.S. private sector investment and involvement in civil space activities.

The basic goals of U.S. space launch policy as stated in the President's Directive on Commercialization of Expendable Launch Vehicles are to: (a) ensure a flexible and robust U.S. launch posture to maintain space transportation leadership; (b) optimize the management and operation of the Space Transportation System (STS) program to achieve routine, cost-effective access to space; (c) exploit the unique attributes of the STS to enhance the capabilities of the U.S. space program; and (d) encourage the U.S. private sector development of commercial launch operations. The policy specifies that:

- The U.S. Government fully endorses and will facilitate the commercialization of U.S. Expendable Launch Vehicles (ELV's).

- The U.S. Government will license, supervise, and/or regulate U.S. commercial ELV operations only to the extent required to meet its national and international obligations and to ensure public safety. Commercial ELV operators must comply with applicable international, national, and local laws and regulations including security, safety, and environmental requirements.

- The U.S. Government encourages the use of its national ranges for U.S. commercial ELV operations. Commercial launch operations conducted from a U.S. Government national range will, at a minimum, be subject to existing U.S. Government range regulations and requirements. Consistent with its needs and requirements, the U.S. Government will identify and make available, on a reimbursable basis, facilities, equipment, tooling, and services that are required to support the production and operation of U.S. commercial ELV's.

- The U.S. Government will have priority use of U.S. Government facilities and support services to meet national security and critical mission requirements. The U.S. Government will make all reasonable efforts to minimize impacts on commercial operations.

- The U.S. Government will not subsidize the commercialization of ELV's but will price the use of its facilities, equipment, and services consistent with the goal of encouraging viable commercial ELV launch activities.

- The U.S. Government will encourage free market competition among the various systems and concepts within the U.S. private sector. The U.S. Government will provide equitable treatment for all commercial launch operators for the sale or lease of government equipment and facilities con-

sistent with its economic, foreign policy, and national security interests.

- The U.S. Government will review and approve any proposed commercial launch facility and range as well as subsequent operations conducted therefrom. Near-term demonstration or test flights of commercial launch vehicles conducted from other than a U.S. Government national range will be reviewed and approved on a case-by-case basis using existing licensing authority and procedures.

Notwithstanding the U.S. Government policy to encourage and facilitate private sector ELV entry into the space launch market, the U.S. Government will continue to make the space shuttle available for all authorized users—domestic and foreign, commercial and governmental—subject to U.S. Government needs and priorities. Through FY 1988, the price of STS flights will be maintained in accordance with the currently established NASA pricing policies in order to provide market stability and assure fair competition. Beyond this period, it is the U.S. Government's intent to establish a full cost recovery policy for commercial and foreign STS flight operations.

### *Implementation*

An interim working group under the Senior Interagency Group (SIG) for Space on Commercial Launch Operations will be formed and co-chaired by the Department of State and NASA. The Working Group will be composed of members representing the SIG (Space) agencies and observers as well as other affected agencies. Additional membership, at a minimum, will include the Federal Aviation Administration and the Federal Communications Commission. This group will be used to (a) streamline the procedures used in the interim to implement existing licensing authority, (b) develop and coordinate the requirements and process for the licensing, supervision, and/or regulations applicable to routine commercial launch operations from commercial ranges, and (c) recommend the appropriate lead agency within the U.S. Government to be responsible for commercial launch activities. Until a final selection of the lead agency is made, the Department of State will serve as the U.S. Government focal point for all inquiries and requests relative to seeking U.S. Government approval for commercial ELV activities.

### *Background*

The National Space Policy identified the STS as the primary launch system for the U.S. Government. The U.S. Government is in the process of phasing out its current ELV operations (i.e., Delta, Atlas, and Titan launch systems) as the capabilities of the STS become sufficient to meet its needs and obligations. Increasing private sector interest in continuing these ELV systems has resulted in requests for a U.S. Government policy on such activities. In addition, an increasing number of new enterprises have been established

with the express purpose of developing commercial space launch capability.

The SIG (Space) was asked to review these issues and make recommendations to the President. This 4-month interagency study concluded that a U.S. commercial ELV capability would offer substantial benefits to the Nation and would be consistent with the goals and objectives of the President's Space Policy.

The existence of a viable commercial ELV industry would add to the general economic vitality of the United States and provide the United States with a more robust space launch capability.

The creation of a domestic ELV industry would also maintain a high technology industrial base unequaled in the free world and provide jobs for thousands of workers while adding to the Federal tax base of the U.S. and a number of States. Each commercial launch conducted in the U.S., rather than by foreign competitors, would strengthen our economy and improve our international balance of payments. Further, continuing commercial ELV operations are expected to spawn numerous spinoffs and supporting activities and strengthen the U.S. position in what is projected to be a

growing commercial market, thereby providing substantial long-term economic benefits to the United States.

In addition to the general economic benefits, both NASA and the Department of Defense would benefit from continuing commercial ELV production and launch. It would provide a more robust U.S. launch capability and offer a domestic backup for the shuttle at essentially no cost to the U.S. Government. The private sector would assume all costs of ELV production now borne by the U.S. Government. There would also be a market for U.S. Government facilities and equipment that would otherwise be underutilized or no longer required. This would also reduce or eliminate U.S. Government close-out costs for discontinuing its ELV operations. It would provide a potential market for excess flight hardware, special purpose tooling and test equipment, as well as propellants which will become excess as the Air Force deactivates the Titan II ICBM's.

In summary, partnership between the U.S. private sector and the U.S. Government will strengthen the U.S. space launch capability, develop a major new industry, contribute favorably to the U.S. economy, and maintain U.S. leadership in space transportation.

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From National Archives and Records Service's *Weekly Compilation of Presidential Documents* for May 16, 1983, pp. 721-723.